UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	Docket Nos. 50-247-LR and 50-286-LR
ENTERGY NUCLEAR OPERATIONS, INC.	)	ASLBP No. 07-858-03-LR-BD01
(Indian Point Nuclear Generating Units 2 and 3)	)	March 30, 2012

TESTIMONY OF ENTERGY WITNESSES LORI POTTS, KEVIN O'KULA, AND GRANT TEAGARDEN ON CONSOLIDATED CONTENTION NYS-12C (SEVERE ACCIDENT MITIGATION ALTERNATIVES ANALYSIS)

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I. WITNESS BACKGROUND

A. Lori Ann Potts ("LAP")

Q1. Please state your full name.

A1. (LAP) My name is Lori Ann Potts.

Q2. By whom are you employed and what is your position?

A2. (LAP) I am a senior consulting engineer to Entergy Nuclear Operations, Inc. ("Entergy") in the areas of severe accident mitigation alternatives ("SAMA") analysis and fire probabilistic risk assessment ("PRA").[1] I have an office at Entergy's Arkansas Nuclear One ("ANO") facility in Russellville, Arkansas.

Q3. Please summarize your professional qualifications.

A3. (LAP) My professional qualifications are provided in my *curriculum vitae* (ENT000004). In brief, I have a Bachelor of Science degree in Nuclear Engineering from

[1] PRA is sometimes referred to as probabilistic safety assessment ("PSA"). The terms PRA and PSA generally are used interchangeably within the nuclear industry.

Pennsylvania State University. I have over 30 years of experience as a technical professional in the nuclear industry in the areas of safety analysis, PRA, deterministic and probabilistic accident and consequence analysis, materials aging management, reactor engineering, and systems engineering. My experience includes performing PRA and severe accident analysis of reactor, emergency system, and containment phenomena under accident conditions. My experience also includes SAMA analysis performed using the MELCOR Accident Consequence Code System 2 ("MACCS2") computer code. As described in more detail below, MACCS2 is a computer code used to evaluate the potential impacts of severe accidents at nuclear power plants on the surrounding public.

I have participated directly in the SAMA analyses for eight nuclear plants, including the SAMA analysis for Indian Point Units 2 and 3 ("IP2" and "IP3," also known jointly as "Indian Point Energy Center" or "IPEC"), and have peer reviewed the SAMA analyses for three additional nuclear plants. I am one of the authors of the Nuclear Energy Institute's ("NEI") industry guidance document for performing SAMA analyses – NEI 05-01, Rev. A, Severe Accident Mitigation Alternatives (SAMA) Analysis Guidance Document (Nov. 2005) ("NEI 05-01") (NYS000287). NEI 05-01 has been endorsed by the Nuclear Regulatory Commission ("NRC").

Q4. Please describe the basis for your familiarity with the IPEC license renewal

A4. (LAP) In my position as senior consulting engineer to Entergy in the area of SAMA analysis, I was involved with the IPEC SAMA analysis from its inception in 2005. I provided advice to the Entergy Fuels and Analysis Department engineers during preparation of the original SAMA analysis and the December 2009 revised SAMA analysis. Also, I reviewed the summaries of those analyses and provided suggestions for improvement before they were submitted to the

NRC. I, therefore, have personal knowledge of the MACCS2 modeling and assumptions used in the IPEC SAMA analysis.

I also have reviewed various materials in preparing this testimony, including those portions of the IPEC LRA relating to SAMAs. I also reviewed New York State's ("NYS") pleadings regarding the admission of NYS-12, amended NYS-12A, amended NYS-12B, and amended NYS-12C; the Board's Orders admitting and consolidating those same contentions; relevant NRC regulations and guidance documents; relevant NRC Staff requests for additional information ("RAIs") and Entergy's responses thereto; the exhibits submitted by NYS that are relevant to my testimony; and the Entergy exhibits cited in my testimony. Finally, I also have reviewed the NRC Staff's evaluation of the IPEC SAMA analysis, as set forth in its final supplemental environmental impact statement ("FSEIS") (discussed further below).

B. <u>Dr. Kevin R. O'Kula ("KRO")</u>

Q5. Please state your full name.

A5. (KRO) My name is Kevin R. O'Kula.

Q6. By whom are you employed and what is your position?

A6. (KRO) I am an Advisory Engineer with URS Safety Management Solutions ("URS") LLC in Aiken, South Carolina.

Q7. Please summarize your professional qualifications.

A7. (KRO) My professional qualifications are provided in my curriculum vitae (ENT000005). In brief, I have over 29 years of experience as a technical professional and manager in the areas of safety analysis methods and guidance development, computer code validation and verification, PRA, deterministic and probabilistic accident and consequence analysis applications for reactor and non-reactor nuclear facilities, source term evaluation, risk management, software quality assurance ("SQA"), and shielding. I obtained my B.S. in Applied and Engineering Physics from Cornell University in 1975, and my M.S. and Ph.D. in Nuclear Engineering from the University of Wisconsin in 1977 and 1984, respectively.

In addition, I have over 20 years of experience using and applying the MACCS2 computer code and its predecessor, MACCS. I co-chaired a U.S. Department of Energy ("DOE") Accident Phenomenology and Consequence evaluation program in the 1990s that evaluated applicable computer models for radiological dispersion and consequence analysis. More recently, I was the technical coordinator of an SQA evaluation of computer codes used for radiological and chemical dispersion in the DOE Complex.

With regard to MACCS2, I have taught MACCS2 training courses for DOE and its contractors at Lawrence Livermore National Laboratory, Los Alamos National Laboratory, Idaho National Laboratory, Oak Ridge, the Waste Isolation Pilot Plant and the DOE Safety Basis Academy. In addition, I was the lead author of a DOE guidance document on the use of MACCS and MACCS2 for DOE safety analysis applications. I was also a member of the State-of-the-Art Reactor Consequence Analyses ("SOARCA") Project Peer Review Committee that provided critical review and comment to Sandia National Laboratories ("Sandia") and the NRC on the use of integrated modeling of accident progression and offsite consequences from postulated severe accidents using both state-of-the-art computational analysis tools and best modeling practices.

Q8. Dr. O'Kula, both you and Ms. Potts have mentioned the MACCS2 code. What is the MACCS2 code, and how is it used in SAMA analyses?

A8. (KRO) MACCS2 is a computer code developed by Sandia under the sponsorship of the NRC and DOE to evaluate the potential offsite radiological consequences from atmospheric releases of radioactivity from nuclear facilities. Specifically, MACCS2 is used to estimate the radiological doses, health effects, and economic consequences that could result from postulated releases of radioactive materials to the atmosphere. It performs these calculations based on plant- and site-specific, regional, industry and standardized regulatory inputs. To my knowledge, MACCS2 is the only NRC-recognized computer code available in the United States that is capable of meeting all of the offsite consequence requirements of a SAMA analysis, including those of calculating population dose and economic cost consequences.

Q9. Please describe the basis for your familiarity with the IPEC license renewal application, particularly the SAMA analysis challenged in NYS-12C.

A9. (KRO) I have thoroughly reviewed the various inputs and assumptions used in Entergy's SAMA analysis (as revised in December 2009) to calculate offsite consequences associated with a postulated severe accident at IPEC, including relevant supporting documentation. I thus have personal knowledge of the MACCS2 modeling, and inputs and assumptions used in the IPEC SAMA analysis.

In preparing my testimony, I also reviewed NYS's pleadings regarding the admission of NYS-12, amended NYS-12A, amended NYS-12B, and amended NYS-12C; the Board's Orders admitting those contentions; relevant regulations and guidance documents; the portions of Entergy's environmental report describing the IPEC SAMA analysis and related Entergy responses to Staff RAIs, the exhibits submitted by NYS that are relevant to my testimony, and the Entergy exhibits cited in my testimony (which include a number of technical papers and studies). Finally, I also have reviewed the NRC Staff's evaluation of the IPEC SAMA analysis, as set forth in its FSEIS.

C. <u>Grant A. Teagarden ("GAT")</u>

Q10. Please state your full name.

A10. (GAT) My name is Grant A. Teagarden.

Q11. By whom are you employed and what is your position?

A11. (GAT) I am Manager for Consequence Analysis for ERIN Engineering & Research, Inc. in Campbell, California.

Q12. Please summarize your professional qualifications.

A12. (GAT) My professional qualifications are provided in my *curriculum vitae* (ENT000007). Briefly summarized, I have 14 years of experience in the nuclear field, including 10 years as a manager and technical professional in the areas of PRA, source term analysis, consequence analysis, and nuclear power plant security risk assessment. I obtained a Bachelor of Science degree in Mechanical Engineering from University of Miami in 1990 and completed the Bettis Reactor Engineering School at the Bettis Atomic Power Laboratory as part of my training in the U.S. Navy nuclear program. I am a member of the American Nuclear Society ("ANS") and serve as the Vice Chair for the writing committee for ANSI/ANS-58.25, *Standard for Radiological Accident Offsite Consequence Analysis (Level 3 PRA) to Support Nuclear Installation Applications*.

I have substantial experience using MACCS2 and preparing Level 3 PRA models for commercial nuclear power plants in the United States. I have performed or overseen the performance of MACCS2 modeling in support of SAMA analyses for ten nuclear power plant sites. I also have developed similar analyses for three proposed new reactor sites and supported reactor vendor development of MACCS2 models for new plant designs.

Q13. Please describe the basis for your familiarity with the IPEC license renewal application, particularly the SAMA analysis challenged in NYS-12C.

A13. (GAT) Like Dr. O'Kula, I have thoroughly reviewed the various inputs and assumptions used in Entergy's SAMA analysis (as revised in December 2009) to calculate offsite consequences associated with a postulated severe accident at IPEC, including relevant supporting documentation. I thus have personal knowledge of the MACCS2 modeling and assumptions used in the IPEC SAMA analysis.

In preparing my testimony, I also reviewed NYS's pleadings regarding the admission of NYS-12, amended NYS-12A, amended NYS-12B, and amended NYS-12C; the Board's Orders admitting those contentions; relevant regulations and guidance documents; the portions of Entergy's environmental report describing the IPEC SAMA analysis and related Entergy responses to Staff RAIs, the exhibits submitted by NYS that are relevant to my testimony, and the Entergy exhibits cited in my testimony (which include a number of technical papers and studies). Finally, I also have reviewed the NRC Staff's evaluation of the IPEC SAMA analysis, as set forth in its FSEIS.

II. OVERVIEW AND SCOPE OF CONSOLIDATED NYS-12C

Q14. Are you familiar with NYS-12, as originally proposed by NYS?

A14. (KRO, GAT, LAP) Yes. We have reviewed the "New York State Notice of Intention to Participate and Petition to Intervene" ("Petition"), dated November 30, 2007, and the "New York Reply in Support of Petition to Intervene," dated February 22, 2008. NYS-12 originally alleged that Entergy's SAMA analysis is deficient because the MACCS2 code used by Entergy calculates decontamination and clean-up costs based on "large-sized" radionuclide particles and, therefore, underestimates severe accident costs. NYS Petition at 140-45. Specifically, NYS-12 alleged that a severe accident at a nuclear power plant like IPEC will result in the dispersion of small-sized radionuclide particles that are significantly more expensive to remove and clean up than the larger-sized particles purportedly assumed within the MACCS2 code. NYS-12 further asserted that the SAMA analysis should incorporate the analytical framework contained in a 1996 Sandia study concerning site restoration costs associated with a plutonium-dispersal accident. *See id.* at 141-42. D. Chanin and W. Murfin, *Site Restoration: Estimation of Attributable Costs from*

Plutonium-Dispersal Accidents, *SAND96-0957, Unlimited Release, UC-502* (May 1996) ("*Site Restoration*") (NYS000249).

Q15. Have you reviewed the Board's Order admitting NYS-12?

A15. (KRO, GAT, LAP) Yes. The Board admitted NYS-12 on July 31, 2008, insofar as "the contention challenges the cost data for decontamination and cleanup used by MACCS2." *Entergy Nuclear Operations, Inc.* (Indian Point, Units 2 & 3), LBP-08-13, 68 NRC 43, 102 (2008). The Board noted that *Site Restoration*, as cited by NYS, questions the appropriateness of decontamination factors (estimates of the effectiveness of cleanup measures) used in severe reactor accidents. *Id.*

Q16. Have you reviewed NYS's subsequent amendments to NYS-12, as admitted and later consolidated by the Board in NYS-12C?

A16. (KRO, GAT, LAP) Yes. NYS amended NYS-12 three separate times to reassert the contention and apply it to the NRC Staff's draft SEIS ("DSEIS"), Entergy's December 2009 revised SAMA analysis, and the Staff's FSEIS. *See* State of New York Contentions Concerning NRC Staff's Draft Supplemental Environmental Impact Statement (Feb. 27, 2009); State of New York's New and Amended Contentions Concerning the December 2009 Reanalysis of Severe Accident Mitigation Alternatives (Mar. 11, 2010); State of New York New Contention 12-C Concerning NRC Staff's December 2010 Final Environmental Impact Statement and the Underestimation of Decontamination and Clean Up Costs Associated with a Severe Reactor Accident in the New York Metropolitan Area (Feb. 3, 2011) ("Amended Contention NYS-12C").

In NYS-12C (the third and final version of the contention), NYS also challenged certain portions of Section G.2.3 of the FSEIS. Specifically, NYS and its former consultant, Mr. David Chanin, argued that the FSEIS: (1) incorrectly accepts and applies cost data for moderate decontamination efforts in lieu of cost data for heavy contamination events, and (2) fails to "scale up" the 1996 *Site Restoration* decontamination cost data to a "hyper-density" urban area such as New York City. *See* Amended Contention NYS-12C at 7; *see id*. at attachment, D.I. Chanin, "Errors and Omissions in NRC Staff's Economic Cost Estimates of Severe Accident Mitigation Alternatives Analysis Contained in December 2010 Indian Point Final Supplemental Environmental Impact Statement (FSEIS), NUREG-1437, Supplement 38" at 1, 3 (Feb. 2011) ("Chanin Report"). The Board admitted NYS-12C on July 6, 2011, consolidating it with NYS-12/12A/12B. *See* Licensing Board Memorandum and Order (Ruling on Pending Motions for Leave to File New and Amended Contentions) at 3-9 (July 6, 2011) (unpublished).

Q17. Have you reviewed the State's initial written statement of position, prefiled direct testimony, and supporting exhibits concerning NYS-12C, which were filed on December 21, 2011?

A17. (KRO, GAT, LAP) Yes, we have reviewed the following documents filed by NYS on December 21, 2011: State of New York Initial Statement of Position [on] Consolidated Contention NYS-12C ("NYS-12C Position Statement") (NYS000240); Pre-Filed Written Testimony of Dr. François J. Lemay Regarding Consolidated NYS-12-C (NYS-12/12-A/12-B/12-C) (Dec. 21, 2011) ("Lemay Testimony") (NYS000241); International Safety Research ("ISR") Report 13014-01-01, "Review of Indian Point Severe Accident Off Site Consequence Analysis" (Dec. 21, 2011) ("ISR Report") (NYS000242); and Exhibits NYS000218 and NYS000240 through NYS000292.

Q18. Have you reviewed other materials in preparation for your testimony?

A18. (KRO, GAT, LAP) Yes, we generally described those materials in Section I above.

Q19. What are the sources of those additional materials?

A19. (KRO, GAT, LAP) Many are documents prepared by government agencies (including NRC, DOE, and EPA), documents prepared by Entergy or the utility industry, and peer-reviewed articles. Those documents include, for example, NRC regulations and guidance documents, Commission decisions, NEI guidance, the IPEC license renewal application (environmental report), the NRC Staff's DSEIS and FSEIS, and relevant technical papers.

Q20. Please direct your attention to what has been marked as Exhibit ENT000001. Do you recognize this document?

A20. (KRO, GAT, LAP) Yes. It is a list of Entergy's exhibits, and includes those documents which we used in preparing the respective portions of our testimony, ENT000004, ENT000005, ENT000007, ENT000009, ENT00010A-D, ENT000011, ENT000013, and ENT000451 to ENT000477.

Q21. Please direct your attention to what has been marked as Exhibits ENT000004, ENT000005, ENT000007, ENT000009, ENT00010A-D, ENT000011, ENT000013, and ENT000451 to ENT000477. Do you recognize these documents?

A21. (KRO, GAT, LAP) Yes. These are true and accurate copies of the documents that we have referred to, used, and/or relied upon in preparing this testimony. Where we have attached only a document excerpt, that is noted on Entergy's exhibit list.

Q22. How do these documents relate to the work that you do as an expert in forming opinions such as those contained in this testimony?

A22. (KRO, GAT, LAP) These documents represent the type of information that persons within our fields of expertise reasonably rely upon in forming opinions of the type offered in this testimony. We note at the outset that we cannot offer legal opinions on the language of the NRC regulations or Commission decisions discussed in our testimony. However, reading those regulations and Commission decisions as technical statements, and using our expertise, we can interpret what those regulations mean relative to an NRC-required SAMA analysis.

III. SUMMARY OF TESTIMONY AND CONCLUSIONS

Q23. What is the purpose of your testimony?

A23. (KRO, GAT, LAP) Our testimony will explain why Entergy's inputs and assumptions relating to decontamination costs are both reasonable and appropriate for a SAMA analysis and compliance with the National Environmental Policy Act ("NEPA") and related NRC requirements and guidance. In doing so, we will fully address NYS's criticisms of Entergy's use of MACCS2, as set forth in the written testimony of its consultant, Dr. Lemay, and the associated ISR Report.

Q24. Please summarize the principal claims made by NYS and its consultant, Dr. Lemay, in NYS's prefiled testimony on NYS-12C.

A24. (KRO, GAT, LAP) NYS and Dr. Lemay allege that Entergy has significantly underestimated the economic costs associated with a severe accident at IPEC by relying on MACCS2 code input values that are not tailored to the specific area surrounding IPEC, and which purportedly do not account for the type of particles released during a severe reactor accident. *See* NYS-12C Position Statement at 2-3, 12-13, 19-20, 42 (NYS000240); Lemay Test. at 7-9, 23, 36, 61, 64-65, 70 (NYS000241). Principally, they assert that:

- Entergy's use of "Sample Problem A" inputs from the *MACCS2 User's Guide* in lieu of site-specific inputs, underestimates the costs of a severe accident at IPEC, because the Sample Problem A inputs that were developed decades ago are not appropriate for the dense population and buildings surrounding IPEC. *See* NYS-12C Position Statement at 17-19, 33-40; Lemay Test. at 9, 21-23, 29-30, 63, 70.

- The decontamination factors and times used by Entergy and accepted by the Staff are not rationally related to IPEC. *See* NYS-12C Position Statement at 21-22, 31-32; Lemay Test. 27-29, 51-55, 70.

- The nonfarm decontamination cost used by Entergy and accepted by the Staff is not rationally related to IPEC. NYS-12C Position Statement 23-30; Lemay Test. at 30-51.

Q25. Do you agree with the assertions made by NYS and Dr. Lemay?

A25. (KRO, GAT, LAP) No. NYS and Dr. Lemay do not correctly characterize the purpose of a SAMA analysis, the role of MACCS2 in such an analysis, or the decontamination model applied in MACCS2. Furthermore, based on our review of the IPEC SAMA analysis, including the associated Level 3 PRA/MACCS2 model, we conclude that Entergy's inputs and assumptions related to decontamination are reasonable and appropriate for an NRC-required SAMA analysis and consistent with longstanding technical and regulatory precedent.

Q26. Please elaborate on the bases for your disagreement with NYS and Dr. Lemay.

A26. (KRO, GAT, LAP) As a threshold matter, it is important to understand the purpose of a SAMA analysis and role of MACCS2 in that analysis. SAMA analysis makes use of probabilistic analysis methods and focuses on both short-term and long-term spatially-averaged impacts from severe accidents for the purpose of making reasonable cost-benefit evaluations under NEPA. Specifically, the MACCS2 severe accident analysis is used to estimate the mean annual offsite population dose and economic costs over the entire 50-mile radius SAMA analysis region, an area of approximately 7,854 square miles. This type of evaluation is intended to yield mean or average estimates of the cost averted for a series of proposed SAMAs, rather than a worst-case portrayal of the effects of a specific event at a specific location or area within the region.

MACCS2 is the standard tool used in the U.S. to support quantification of offsite population dose and economic cost consequences from postulated reactor accidents, as is done in a SAMA analysis. Among the U.S. consequence codes that are publicly available, MACCS2 is unique in its capability for modeling the relevant atmospheric transport and dispersion phenomenology and quantifying the consequences of interest needed for nuclear power plant severe accident risk studies, including SAMA analyses. Other U.S. codes are available to assess dose and dose pathways, recovery options and strategies, but only MACCS2 can evaluate these consequences and potential economic impacts in the context of a PRA-based, SAMA cost-benefit analysis.

In view of the above, it is clear that a number of the studies relied upon by NYS and Dr. Lemay are simply not relevant to the objectives of a nuclear power plant SAMA analysis. For example, several of the studies relied upon by NYS focus on postulated radiological releases from nuclear weapon or "dirty bomb" detonations and seek to assess the economic costs of a single release event at a single location (*e.g.*, New York City). As explained below, these studies are based on assumptions that have no applicability here. Consequently, they have no relevance to the IPEC SAMA analysis and provide no support for NYS's contention.

NYS's criticisms of Entergy's inputs to the MACCS2 code also lack merit. It is true that certain MACCS2 inputs used by Entergy are consistent with the inputs used in MACCS2 Sample Problem A. However, those inputs have been subject to extensive peer review since the late 1980s (supporting the landmark NUREG-1150 PRA study published in 1990) and continue to be used in licensee PRA and SAMA analyses and state-of-the-art severe accident analyses conducted by the NRC. That is, they are not arbitrarily-selected "default" values as NYS asserts; they are values with a well-established technical pedigree that is widely recognized and accepted by the PRA community.

Another critical flaw in NYS's case is its failure to accurately portray the MACCS2 decontamination model. The primary goal of the decontamination plan as modeled in MACCS2 is to cost-effectively reduce doses to meet applicable land habitability criteria for a resident population in the region of interest to allow population resettlement. It is not intended to bound or account for all potential decontamination-related activities that may arise in the years following a severe accident at a nuclear power plant (e.g., decontamination of specific structures such as schools after population resettlement). NYS and Dr. Lemay incorrectly suggest otherwise.

As applied in SAMA analyses, MACCS2 models the decontamination actions that may be taken during the period of weeks or months after deposition of radioactive contamination at the end of the "emergency phase" (typically modeled as the first seven days) following a severe accident. The decontamination model input data define the strategies that are possible, their effectiveness, and their cost. Up to three "decontamination levels" may be defined in MACCS2, where a given decontamination level represents a combination of decontamination activities that reduce the projected long-term doses by a factor called the dose reduction factor ("DRF"). Based on the defined habitability criteria and costs for each decontamination level, MACCS2 determines if decontamination is needed and, if so, how long to employ a given strategy to achieve a projected dose to inhabitants, *i.e.*, a habitability criterion, that meets allowed federal or state dose limits. This approach, consistent with NRC-endorsed guidance, has to our knowledge been applied in *all* NRC-approved license renewal SAMA analyses to date. The same approach also has been applied by the NRC in its State-of-the-Art Reactor Consequence Analyses ("SOARCA") project, which seeks to develop updated and more realistic severe accident analyses by including significant plant improvements and updates not reflected in earlier NRC assessments. Due to the complex modeling performed by, and the numerous inputs into the MACCS2 code, our testimony discusses in detail how MACCS2 is used in a SAMA analysis.

NYS's criticisms of Entergy's decontamination modeling in the SAMA analysis hinge largely on two MACCS2 parameters: decontamination time (TIMDEC) and nonfarm decontamination cost (CDNFRM). In MACCS2, the decontamination time variable, TIMDEC, represents the time period during which persons are temporarily interdicted (*i.e.*, kept away from their residences) while decontamination activities are completed to reduce the dose by the specified dose reduction factor. Once the time period modeled by TIMDEC is completed, MACCS2 models the relocation of persons back to their residences if the specified habitability criteria are satisfied. Thus, TIMDEC establishes the minimum time that an individual is relocated due to dose constraints. As we explain further in our testimony, the 60-day and 120-day TIMDEC values used in the IPEC SAMA analysis are readily justified on both historical and technical grounds.

In contrast, the alternative decontamination times proposed by Dr. Lemay in the ISR Report (which range from 2 to 30 years) are fundamentally inconsistent with the decontamination and interdiction modeling assumptions built into and applied by MACCS2. Specifically, forcing a long decontamination period in the MACCS2 analysis via the variable TIMDEC, as proposed by Dr. Lemay, distorts the dose reduction resettlement optimization strategy inherent in MACCS2. For example, if a value of 15 years is used for TIMDEC, MACCS2 will not return any impacted individuals to their residences until 15 years have passed. This is not appropriate for the modeling of a severe accident event, because many individuals will be able to return to their residences following modest decontamination activities. Indeed, Dr. Lemay could only accommodate his alternative, much larger TIMDEC values by altering the FORTRAN source code in MACCS2. To require licensees to modify the source code of a sophisticated, NRC-accepted software package to extend the range of established input variables is not prudent (due to quality assurance concerns), practical, reasonable, or warranted under NEPA.

NYS's criticisms of Entergy's nonfarm decontamination cost (CDNFRM) values also are invalid. Entergy used CDNFRM values consistent with those used in NUREG-1150 (and hence

MACCS2 Sample Problem A) and adjusted them to 2005 (the basis year for the IPEC SAMA analysis) dollars in accordance with NRC-approved guidance. Dr. Lemay's proposed values for the CDNFRM variable are inappropriate because they are derived from cost data that have no applicability to a nuclear power plant SAMA analysis, are based on selective and incorrect use of the data, and lack adequate technical justification.

For these and other reasons detailed in our testimony below, we conclude that NYS's allegations in NYS-12C lack merit, and that for purposes of a SAMA analysis, Entergy has used reasonable and appropriate values for the MACCS2 parameters challenged by NYS.

IV. <u>REGULATORY AND TECHNICAL BACKGROUND</u>

A. <u>Overview of SAMA Analysis</u>

Q27. What is a severe accident?

A27. (KRO, GAT, LAP) The NRC defines a severe accident as a beyond design-basis accident "involving multiple failures of equipment or function, whose likelihood is generally lower than design-basis accidents but where consequences may be higher." NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Vol. 1, at 5-1 (May 1996) ("GEIS") (NYS00131C). The GEIS provides an evaluation of severe accident impacts that applies to all U.S. nuclear power plants. *See id*. at 5-1 to 5-20. Based on the GEIS evaluation of severe accidents, 10 C.F.R. Part 51 concludes that the "[t]he probability weighted consequences of atmospheric releases, fallout onto open bodies of water, releases to ground water, and societal and economic impacts from severe accidents are small for all plants." 10 C.F.R. Pt. 51, Subpt. A, App. B, Tbl. B-1 (Postulated Accidents; Severe accidents). Thus, by definition, a SAMA analysis considers postulated events whose probability of occurrence is so low that they are excluded from the spectrum of design-basis accidents postulated by NRC regulations.

Q28. Please describe the purpose of a SAMA analysis.

A28. (LAP, KRO, GAT) According to industry guidance on SAMA analyses, "[t]he purpose of the analysis is to identify SAMA candidates that have the potential to reduce severe accident risk and to determine if implementation of each SAMA candidate is cost beneficial." NEI 05-01, at 1 (NYS000287). Specifically, a SAMA analysis identifies potential changes to a nuclear power plant, or its operations, that could reduce the already-low risk (the likelihood and/or the impact) of a severe accident for which the benefit of implementing the change may outweigh the cost of implementation. Changes to the nuclear power plant that could reduce the risk of a severe accident include plant modifications or operational changes (*e.g.*, improved procedures and augmented training of control room and plant personnel). These potential changes are referred to as SAMAs or SAMA candidates.

Q29. What is the purpose of NEI 05-01?

A29. (LAP, KRO, GAT) NEI 05-01 was developed by several SAMA analysis experts in the field, including Ms. Potts, and was issued by NEI in November 2005. *See* NEI 05-01 (title page and acknowledgements) (NYS000287). It provides guidance to reactor license renewal applicants for completing the SAMA analysis required by NRC's NEPA regulations found in 10 C.F.R. Part 51. It identifies the information that an applicant should include so that the SAMA analysis will be complete. *See id*. at i. NEI 05-01 guidance relies upon regulatory analysis techniques presented in NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook" ("NUREG/BR-0184") (Jan. 1997) (ENT00010A-D), and draws from experience gained from previous SAMA analyses and NRC reviews thereof. *Id*.

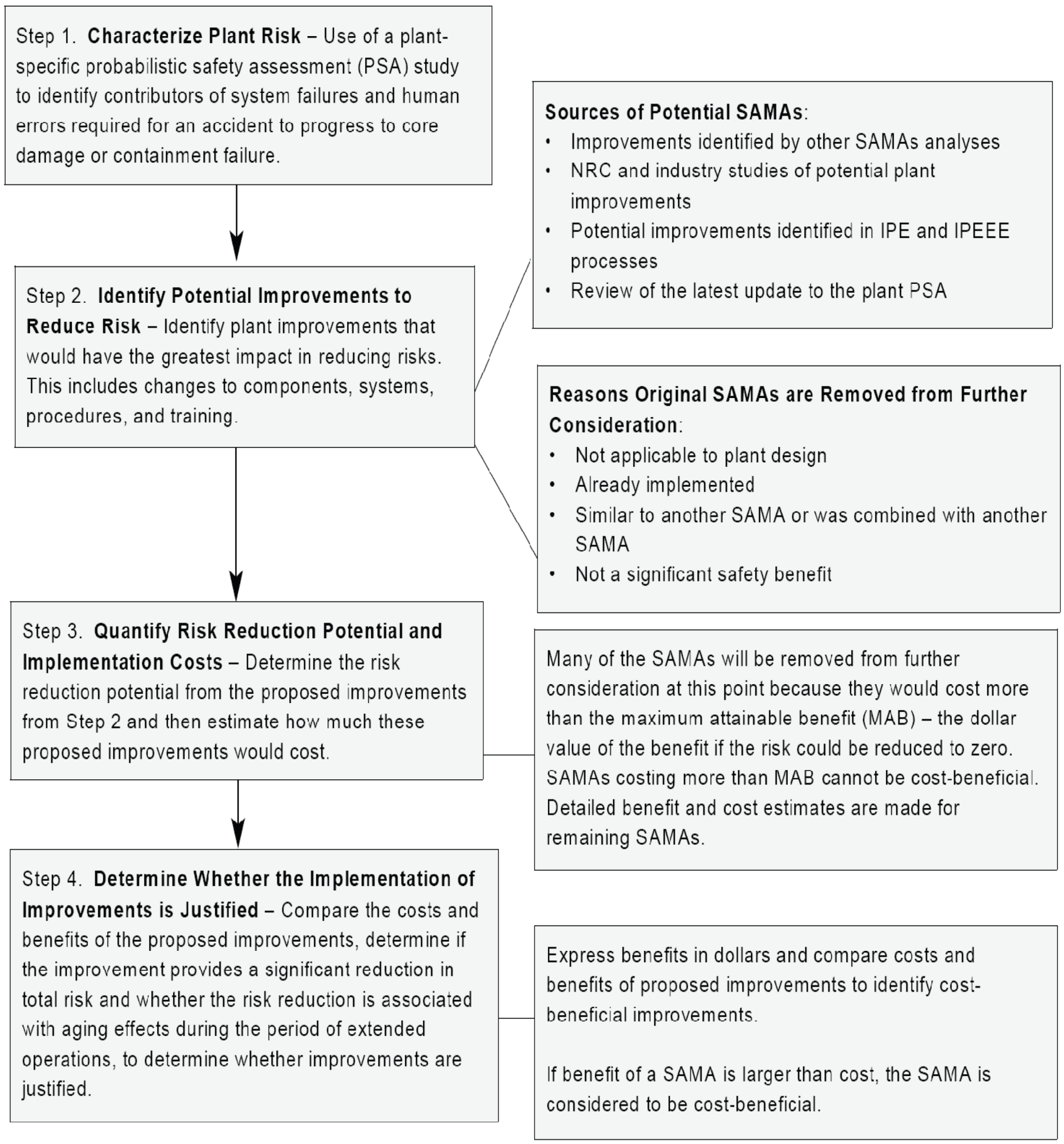
Q30. Has the NRC endorsed the use of NEI 05-01 to perform SAMA analyses?

A30. (LAP, KRO, GAT) Yes. The Staff has recommended that applicants for license renewal follow the guidance provided in NEI 05-01, Revision A when preparing their SAMA analyses. Notice of Availability of the Final License Renewal Interim Staff Guidance LR-ISG-2006-03: Staff Guidance for Preparing Severe Accident Mitigation Alternatives Analyses, 72 Fed. Reg. 45,466, 45,467 (Aug. 14, 2007) (ENT000451). According to the Staff, NEI 05-01, Revision A, "facilitates complete preparation of SAMA analysis submittals." *Id.*

Q31. Broadly speaking how is a SAMA analysis performed?

A31. (LAP, KRO, GAT) As summarized in Figure 1 below, excerpted from NUREG-1850, "Frequently Asked Questions on License Renewal of Nuclear Power Reactors" (at 4-33) (Mar. 2006) (ENT000011), a SAMA analysis involves four major sequential steps: (1) characterizing the overall plant severe accident risk and the leading contributors to the risk; (2) identifying potential plant improvements (*i.e.*, SAMA candidates) that could reduce the risk of a severe accident; (3) quantifying the risk-reduction potential and the implementation cost for each SAMA candidate; and (4) determining whether implementation of the SAMA candidates may be cost-effective.

SAMA analysis evaluates a wide range of potential long-term severe accident consequence scenarios for the purpose of making reasonable cost-benefit evaluations under NEPA. Because it is concerned with mean annual consequences, a SAMA analysis is not designed to model a single radiological release event under specific meteorological conditions at a single moment in time. Instead, it models numerous accident release conditions that could, based on *probabilistic* analysis, occur at any time under varying weather conditions during a one-year period. The goal is to estimate annual average impacts for the entire 50-mile radius study area.



<u>Figure 1</u>. Generalized Process for Identifying and Evaluating Potential Severe Accident Mitigation Alternatives (from NUREG-1850, Frequently Asked Questions on License Renewal of Nuclear Power Reactors (Mar. 2006)).

B. <u>Overview of the MACCS2 Code and Its Relationship to Prior NRC Assessments of Severe Accidents</u>

Q32. Why was the MACCS2 code developed?

A32. (KRO, GAT) The MACCS2 code was specifically developed to address the methodological requirements associated with PRAs of the type used in SAMA analyses. The code's genesis can be traced to the development of CRAC, an early predecessor code to MACCS2. *See* NUREG/CR-6613, "Code Manual for MACCS2," Vol. 1, User's Guide at 1-1 (May 1998) ("*MACCS2 User's Guide*" or "NUREG/CR-6613") (NYS000243). In 1975, the Reactor Safety Study, also known as WASH-1400, was published to present an assessment of risk associated with potential accidents at commercial nuclear power plants. *Id.* (discussing WASH-1400 (NUREG-75/014), "Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants" (1975) (ENT000452)). WASH-1400 presented the first comprehensive PRA of hypothetical nuclear power plant accidents. *Id.* The estimation of accident risks in WASH-1400 required the consideration of both frequencies of accident occurrence as well as the accident consequences.

Q33. What is the CRAC code?

A33. (KRO, GAT) As part of the WASH-1400 study, Sandia developed the Calculation of Reactor Accident Consequences ("CRAC") code to calculate the health and economic consequences of accidental releases of radioactive material to the atmosphere. NUREG/CR-6613, Vol. 1 at 1-1 (NYS000243). CRAC utilized a Gaussian plume model due to its greater computational efficiency, thereby facilitating multiple code runs for a given analysis. In 1982, Sandia released CRAC2, which incorporated major improvements to the original CRAC code in the areas of weather sequence sampling and emergency-response modeling. *Id.* CRAC2 was used for diverse applications such as the 1982 Sandia Siting Study, as documented in NUREG/CR-2239, "Technical Guidance for Siting Criteria Development" (1982) (ENT000453). *Id.* at 1-2.

Q34. What was the purpose of the 1982 Sandia Siting Study?

A34. (KRO, GAT) The NRC contracted with Sandia to develop a technical guidance report for siting future reactors. The NRC requested guidance on (1) criteria for population density and distribution surrounding future sites and (2) standoff distances of plants from offsite hazards. NUREG/CR-2239 at 1-1 (ENT000453). Because the work was primarily focused on developing generic siting criteria, this study used five generic source terms for analyzing the consequences and socio-economic impacts of possible plant accidents at 91 existing or proposed reactor sites (including Indian Point). *Id.* at 1-5, 2-1. These source terms were derived from the Reactor Safety Study (WASH-1400) and subsequent evaluations.

During this study, it became apparent that CRAC2 did not offer sufficient flexibility for the performance of sensitivity studies and the evaluation of alternative parameter values for its models. NUREG/CR-6613, Vol. 1 at 1-2 (NYS000243). As a result, Sandia developed the MELCOR Accident Consequence Code System ("MACCS") code to address those issues by facilitating the performance of site-specific calculations, evaluation of sensitivities and uncertainties, and the future incorporation of new phenomenological models. *Id.* The first version of MACCS released to the public, version 1.4, was distributed by Sandia in 1987. *Id.* MACCS was used for consequence analysis calculations in the study now commonly referred to as NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants" (Dec. 1990) (NYS00252A-C).

Q35. What is the NUREG-1150 study, and what is its significance?

A35. (KRO, GAT) NUREG-1150 (along with related supporting technical documentation in NUREG/CR-4551) documents the results of an extensive NRC-sponsored PRA that examined five plants with different reactor and containment designs to gain an understanding of risks for these particular plants. NUREG-1150 was important in establishing the use of peer reviewed selection of models and input parameter values by groups of subject matter experts. The five nuclear power plants analyzed in NUREG-1150 were: (1) Surry, a 3-loop Westinghouse PWR with a sub-atmospheric containment; (2) Zion, a 4-Loop Westinghouse PWR with a large dry containment; (3) Sequoyah, a 4-loop Westinghouse PWR with an ice condenser containment; (4) Peach Bottom, a BWR-4 reactor with a Mark I containment; and (5) Grand Gulf, a BWR-6 reactor with a Mark III containment. For Surry and Peach Bottom, the study included analyses of both internal and external events. *See* NUREG-1150, Vol. 1 at 1-1 to 1-4 (NYS00252A).

NUREG-1150 presented population dose results for a 50-mile radial region around each of five representative nuclear power plants, as well as population dose results for a broader region (*i.e.*, greater than 50 miles), that is typically referred to as the "entire region." *Id.* at 2-3, 2-20. The improved PRA methodology used in the NUREG-1150 study greatly enhanced the understanding of risk at nuclear power plants and is considered a significantly updated and improved revision to the Reactor Safety Study. In fact, the NUREG-1150 / NUREG/CR-4551 methods and analyses continue to be used as appropriate benchmarks today for PRA in the U.S. commercial power reactor industry. NEI 05-01, at 13. Also, NYS000282, Table 7.2-9 at 7-39. And, as discussed below, certain MACCS2 inputs at issue here have a direct nexus to the NUREG-1150 study.

Q36. You mentioned NUREG/CR-4551. Please briefly describe that document and its relevance here.

A36. (KRO, GAT) NUREG/CR-4551, which also was published in December 1990, is a companion document to NUREG-1150. Specifically, it is one of numerous documents prepared to support the development of NUREG-1150. It is a substantial work product comprising seven volumes. In particular, NUREG/CR-4551, SAND86-1309, Vol. 2, Rev. 1, Part 7, "Evaluation of Severe Accident Risks: Quantification of Major Input Parameters" (December 1990) (NYS000248) specifically discusses major MACCS input parameters used in the NUREG-1150 study.

Q37. When did MACCS2 replace MACCS and why was it replaced?

A37. (KRO, GAT) MACCS experienced wide use within the U.S. and abroad for the evaluation of nuclear power plant safety. Although MACCS was originally intended for use in connection with nuclear power plants, a sizable fraction of the code's users utilized MACCS to assess the safety of DOE facilities due to its versatility in estimating doses and health effect risks from the accidental atmospheric releases of radionuclides. NUREG/CR-6613, Vol. 1 at 1-3 to 1-4 (NYS000243). After successive versions of MACCS were applied to DOE facilities, it became apparent that the set of included radionuclides selected for commercial reactor applications did not fully address certain DOE facilities. *Id.* at 1-4. To address this issue, and to implement a number of other changes that would enhance the code's utility for all types of reactor and nonreactor nuclear facilities, MACCS2 was developed and first released to the public in 1998. *Id.* MACCS2 provides an analysis tool for use in assessing potential accidents at a broad range of reactor and nonreactor nuclear facilities.

Q38. Is MACCS2 still in wide use today?

A38. (KRO, GAT) Yes. As discussed further below, the principal phenomena considered in MACCS2 are atmospheric transport, short-term and long-term mitigative actions (*e.g.*, sheltering in place, evacuation, relocation, land remediation), short-term and long term and exposure pathways (including ingestion dose, land remediation dose, and dose received from individuals living for decades on marginally contaminated land), deterministic and probabilistic health effects (*e.g.*, doses to individual organs, cancers), and economic costs. NUREG/CR-6613, Vol. 1 at 1-2 (NYS000243). Among the U.S. consequence codes that are publicly available, MACCS2 is unique in its capability for modeling these many attributes of interest for nuclear plant accident risk studies, including SAMA analyses. *Id.* Both DOE and the NRC have sponsored MACCS2 development efforts, which continue to this day. *Id.* at 1-4.

Q39. Do you consider MACCS2 to be a state-of-the-art tool for analyses of the type performed in a SAMA analysis?

A39. (KRO) Yes. The MACCS2 code is the standard tool used in the U.S. to support quantification of offsite population dose and economic cost consequences from postulated nuclear power plant accidents. There are no known U.S. computer codes other than MACCS2 that can evaluate these consequences and potential economic impacts in the context of a PRA-based, SAMA cost-benefit analysis. In fact, in the contested license renewal proceeding for Pilgrim Nuclear Power Station, in which I participated as an expert witness on Entergy's behalf, the Commission described MACCS2 as "the most current, established code for NRC SAMA analysis." *Entergy Nuclear Generation Co.* (Pilgrim Nuclear Power Station), CLI-10-22, slip op. at 9 (Aug. 27, 2010).

MACCS2 continues to have a large international user community for nuclear reactor and nonreactor safety analysis, chiefly to support PRAs and cost-benefit studies (including SAMA analyses), but also for safety basis analysis in the DOE Complex. *See* DOE Office of Health, Safety and Security, Safety Software Quality Assurance - Central Registry, *available at* http://www.hss.doe.gov/nuclearsafety/qa/sqa/central_registry.htm (last visited March 29, 2012) (ENT000453). In addition, MACCS2 is periodically updated and subject to peer review as part of the continual improvement process in its software life cycle. As summarized earlier, the NRC and Sandia have invested in maintenance and development of the MACCS2 code through the years to support severe accident consequence assessment and PRA/SAMA analyses. Currently, the NRC and Sandia are concluding a peer-reviewed activity called the State-of-the-Art Reactor Consequence Analyses (SOARCA) project, in which they are using MACCS2 to model the offsite health effect consequences of atmospheric releases of radioactive material. *See generally*, NUREG-1935, State-of-the-Art Reactor Consequence Analyses (SOARCA) Report, Draft Report for Public Comment (Jan. 2012) ("Draft NUREG-1935") (ENT000455); NUREG/CR-7110, Vol. 1, "State-of-the-Art Reactor Consequence Analyses Project: Peach Bottom Integrated Analysis" (Jan. 2012) ("NUREG/CR-7110, Vol. 1") (ENT000456); NUREG/CR-7110, Vol. 2, State-of-the-Art Reactor Consequence Analyses Project: Surry Integrated Analysis (Jan. 2012) ("NUREG/CR-7110, Vol. 2") (ENT000457).

Q40. In the context of a SAMA analysis, will data from the effects and consequences of an event such as a nuclear weapon or "dirty bomb" (*e.g.*, a radiological dispersal device or "RDD") detonation be relevant as input data to the MACCS2 code?

A40. (KRO, GAT) No, data from nuclear weapon and dirty bomb detonations are not directly applicable or relevant in the context of an NRC SAMA analysis or for helping develop input data to the MACCS2 code. While the MACCS2 code can process the atmospheric dispersion of radiological material released from such events and calculate expected consequences to surrounding populations, these events are significantly different from those postulated in a severe accident occurring in a nuclear power plant.

As we explain further below, a SAMA analysis is a probabilistic analysis focused on long-term and spatially-averaged impacts from severe accident events, in which the population dose and economic effects are averaged both over the area within 50 miles of the site and over the expected variations in meteorological patterns.

Q41. Please briefly describe the SOARCA project mentioned in A26 and A39 above.

A41. (KRO) The NRC initiated the State-of-the-Art Reactor Consequence Analyses (SOARCA) project in 2006 to develop revised best estimates of the offsite radiological health consequences of severe reactor accidents. The project's principal objective was to develop updated and more realistic severe accident analyses by including significant plant changes and updates not reflected in earlier NRC assessments. SOARCA included consideration of plant system improvements, improvements in training and emergency procedures, offsite emergency response, and security-related improvements, as well as plant changes like power uprates and lengthened operating times.

The SOARCA analyzed two plants that are typical of the two U.S. commercial reactor types: a boiling-water reactor ("BWR") plant at the Peach Bottom Atomic Power Station in Pennsylvania, and a pressurized-water reactor ("PWR") at Surry Power Station in Virginia. These two plants also took part in earlier accident analyses performed by the NRC, such as those documented in the 1982 Sandia Siting Study and the 1990 NUREG-1150 study. The Staff analyzed one reactor at each site. In January 2012, the NRC published the results of its assessment in Draft NUREG-1935 (ENT000455) and plant-specific technical supporting information reports for Peach Bottom (NUREG/CR–7110, Vol. 1 (ENT000456)) and for Surry (NUREG/CR–7110, Vol. 2 (ENT000457)).

The SOARCA project used computer modeling techniques to understand how a reactor might behave under severe accident conditions, and how a release of radioactive material from the plant might impact the public. Draft NUREG-1935 at 1-3 (ENT0000455). Specifically, it uses MELCOR to model the severe accident scenarios within the plant, and MACCS2 to model the offsite health effect consequences of any atmospheric releases of radioactive material. *Id.* at 3.

With regard to MACCS2, draft NUREG-1935 states: "An expert panel reviewed the MACCS2 code and modeling choices in August 2006, before specific work on Surry and Peach Bottom began. This expert panel review and the NRC staff recommendations influenced much of the development undertaken specifically to support the SOARCA work." *Id.* at 49. I was a member of the expert panel to which draft NUREG-1935 refers. The SOARCA study team and expert panel thus judged MACCS2 to be the most suitable tool for calculating the offsite health consequences of an airborne release of radioactive material using site-specific information for the two plant regions and radiological release (i.e., source term) data from MELCOR.

Q42. Has MACCS2 commonly been used in analyses performed to the meet the requirements of NEPA?

A42. (KRO, GAT) Yes. As noted in the *MACCS2 User's Guide*, MACCS2 and its predecessor MACCS have been widely used for NEPA studies since the early 1990s. NUREG/CR-6613, Vol. at 1-6 to 1-7 (NYS000243). For example, DOE has issued numerous large-scope environmental impact statements (EISs) that relied on MACCS2 and MACCS, including EISs related to tritium supply and recycling, foreign research reactor fuel, stockpile stewardship and management, the Pantex plant site-wide EIS, the storage and disposition of fissile materials, and disposition of surplus highly-enriched uranium. *Id.* MACCS2 also is used in safety basis analysis within the DOE Complex. *Id.* at 1-7. Moreover, MACCS/MACCS2 has been used by numerous NRC license (*e.g.*, COL) and license renewal applicants in the preparation of their environmental reports, as required by NEPA and Part 51.

Q43. To your knowledge, has a code other than MACCS/MACCS2 been used in an NRC license renewal SAMA analysis to estimate the atmospheric transport and dispersion of postulated releases and model subsequent consequences?

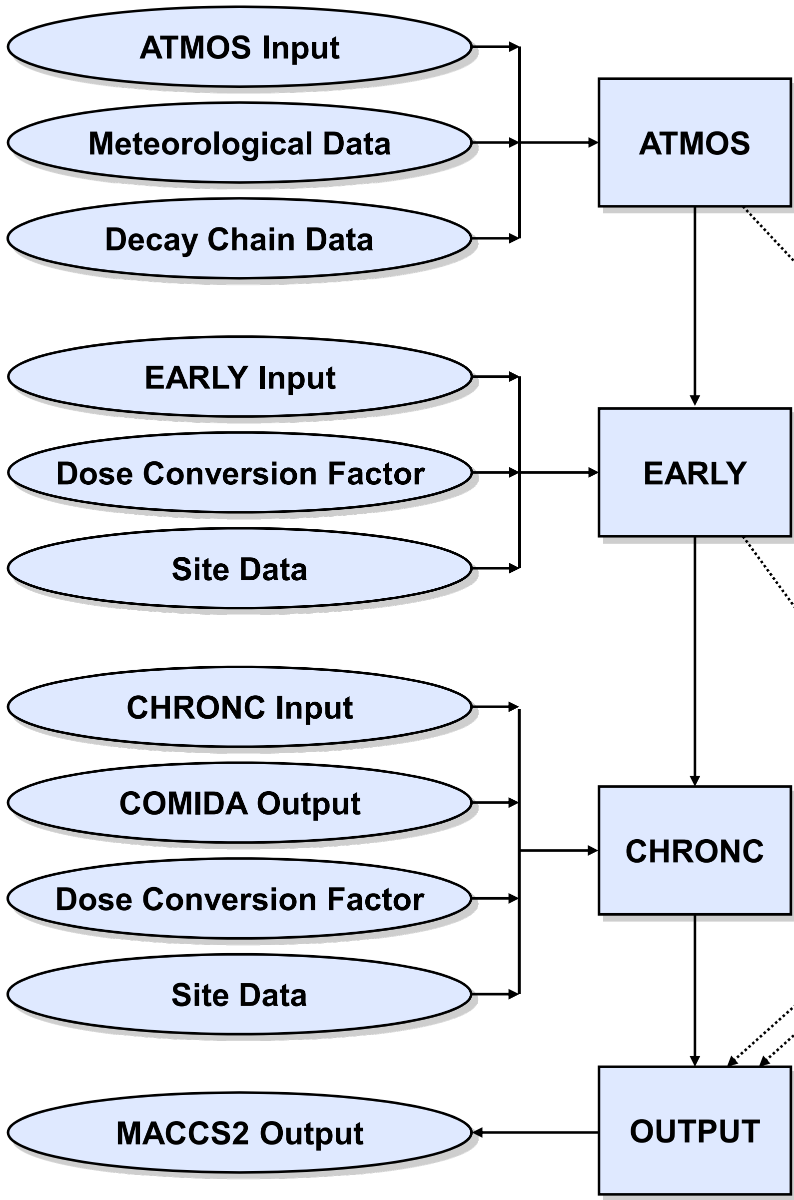
A43. (KRO, GAT, LAP) No. To our knowledge no other atmospheric transport and dispersion code has been used in the U.S. for the purposes of SAMA analysis.

C. <u>Description of MACCS2 Code Structure and Functionality</u>

Q44. Please describe the basic analytical structure of the MACCS2 code, including its various modules.

A44. (KRO, GAT, LAP) The MACCS2 code executes three modules in sequence to calculate consequence values necessary for a SAMA analysis—the ATMOS, EARLY, and CHRONC modules. *See* NUREG/CR-6613, Vol. 1 at 2-1 (NYS000243). The ATMOS module performs calculations pertaining to atmospheric transport, dispersion, and deposition of radioactive material, and to radioactive decay of that material both before and after its release into the atmosphere. The EARLY module uses the calculated air and ground concentrations, plume size, and timing information for all plume segments calculated by ATMOS and other inputs (*e.g.*, population distribution) to calculate consequences due to radiation exposure in the "emergency phase" (*e.g.*, the first seven days from the time of release). *Id*. at 2-2. The CHRONC module uses atmospheric transport, dispersion, and deposition information calculated by ATMOS and other inputs (*e.g.*, population distribution and economic data) to calculate (1) the long-term phase consequences due to exposure after the emergency phase (*i.e.*, the duration of the long-term exposure period is set to 30 years in most SAMA analyses); and (2) the economic impacts from each accident sequence and the economic costs of the short-term and long-term protective actions.

See id. at 2-2 & 2-10. Figure 2 illustrates the consequence sequence progression and the three primary MACCS2 modules, ATMOS, EARLY, and CHRONC.



<u>Figure 2</u>. Phenomenological Model Logic in MACCS2 Code. (Presented by Dr. Nathan Bixler, Sandia National Laboratories, PSA 2011 Workshop, "Overview of MACCS2 Models", Wilmington, NC March 11, 2011) (ENT000458). COMIDA refers to the food ingestion dose model in MACCS2 that is executed prior to MACCS2 analysis.

The general process of determining consequences from each particular postulated release follows a three-step calculation sequence as follows:

1. Execution of the three MACCS2 computational modules: ATMOS, EARLY, and CHRONC are run for a specific set of site-specific meteorological conditions, *i.e.*, a weather sequence, to produce a single value of population dose and economic cost for each postulated source term.

2. Simulation of each postulated release for multiple weather sequences: Up to a total of 160 sets of randomly selected weather sequences, postulated to occur in each of the 16 principal compass sector directions (as discussed further below), are analyzed for each source term. This results in a total of 2,560 individual consequence results for each postulated source term.

3. Determination of the mean value: The mean population dose and mean economic cost consequence from the 2,560 sets of calculated consequence values and their corresponding probabilities are calculated by applying a mathematical formula for determining the mean of a statistical distribution. Statistically, these are the *mean consequence* values for the postulated source term being modeled.

Q45. In describing the operation of MACCS2, you have referred to specific phases or time periods (*e.g.*, the emergency phase). Please explain this concept and why it is important.

A45. (KRO, GAT) In SAMA analysis modeling of severe accident consequences, the period following the postulated accidental release of a radioactive plume is typically divided into two phases in MACCS2. The two phases include: (1) an emergency phase, and (2) a long-term phase. This is important because the dose pathways and mitigation actions modeled by MACCS2 to limit doses are associated with each phase.

In the early or emergency phase, which is modeled in most SAMA analyses as the first seven days from the time of release, the radioactive atmospheric plume is transported and dispersed by the ambient wind direction and speed using a polar coordinate representation of the 50-mile SAMA region. NUREG/CR-6613, Vol. 1 at 2-1 to 2-4 (NYS000243). The calculation of radiation doses during the early phase considers five pathways: (1) direct external exposure to radioactive material in the plume (cloudshine), (2) exposure from inhalation of radionuclides in the cloud

(cloud inhalation), (3) exposure to radioactive material deposited on the ground (groundshine), (4) inhalation of resuspended material (resuspension inhalation), and (5) skin dose from material deposited on the skin. During the emergency phase, mitigative actions to reduce potential population doses include evacuation, sheltering, and dose-dependent relocation.

The long-term phase begins, at each successive downwind distance point travelled by the plume, upon the conclusion of the emergency phase and estimates radiological exposures and consequences over a period of time lasting approximately thirty years in most current-day SAMA analyses. The exposure pathways considered during this period are groundshine, resuspension inhalation, and food and water ingestion. The exposure pathways considered are those resulting from ground-deposited material. A number of protective measures can be modeled in the long-term phase in order to reduce doses to user-specified levels: decontamination, temporary interdiction, and condemnation. Relocation of resident populations can be modeled in both the emergency phase and the long-term phase.

Q46. In describing the two-phase model implemented in the MACCS2 code, a polar grid model is described for the purposes of calculating the SAMA analysis population dose and offsite economic consequences. Please explain how the polar coordinate grid system applies to the 50-mile radius region around IPEC.

A46. (KRO, GAT, LAP) The fifty-mile radius region is divided into a polar coordinate grid with IPEC at its center as is represented in Figure 3. This figure shows the 16 standard meteorological wind direction sectors that are used in MACCS2 analyses (*e.g.*, N, NNE, etc.). *See*

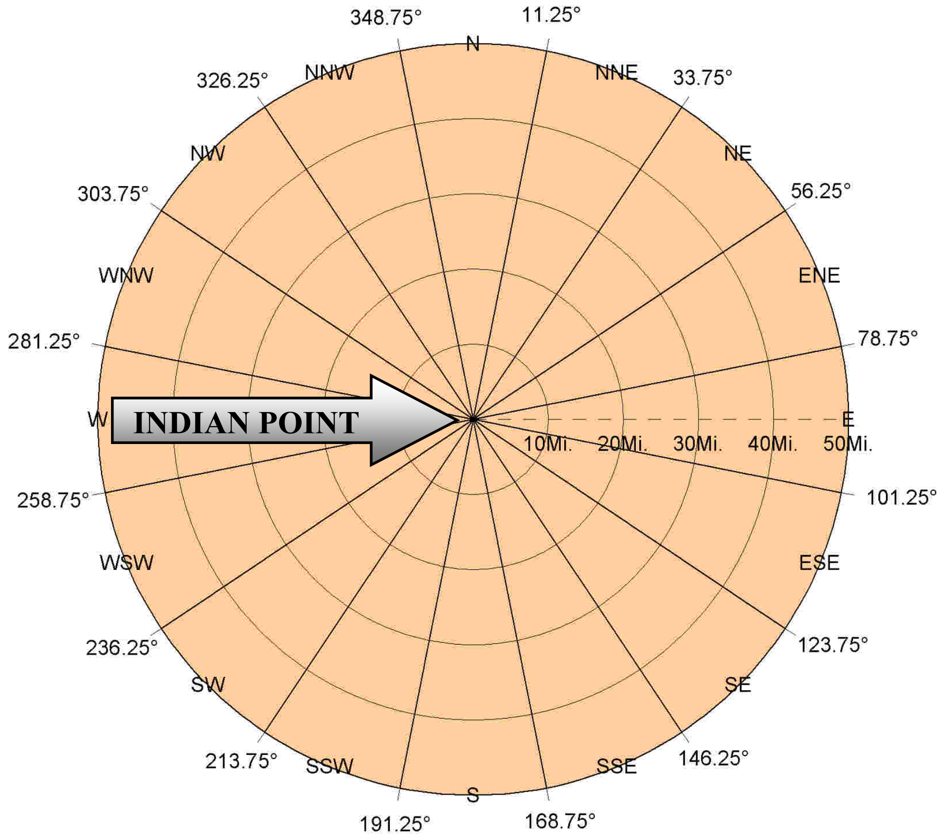


Figure 3. **MACCS2 Polar Coordinate Grid, Centered Around IPEC**

NUREG/CR-6613, Vol. 1 at 2-3 to 2-5 (NYS000243). For the IPEC site, this polar grid comprises a series of radial rings centered on the site with boundaries at radii of 0.2, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, and 50 miles. As seen in Figure 3 (which shows only five radial rings at 10, 20, 30, 40, and 50 miles), each of the radial rings is transected by 16 wind direction sectors emanating from the plant. All MACCS2 calculations are stored on the basis of this polar coordinate grid system. *Id.* at 2-3.

Q47. How does MACCS2 use a polar coordinate grid system to calculate offsite public dose and economic costs?

A47. (KRO, GAT) In the full IPEC MACCS2 probabilistic assessment of a given source term, 155 randomly-selected weather sequences from the calendar year 2000, postulated to occur in each of the 16 principal compass sector directions and for the associated population distributions, were analyzed for each source term. MACCS2 calculates the population dose and economic cost for each of the individual grid spatial elements affected by the simulated radiological release and then sums the results over all of the grid spatial elements. This process yields a distribution of population dose and offsite economic cost results for each postulated accident scenario source term. Each result is weighted by its probability of occurrence. *See* NUREG/CR-6613, Vol. 1 at 2-19 (NYS000243). Thus, the final calculation of a mean population dose or offsite economic cost evaluates 2,480 potential results for the population dose and weights them by their probability of occurrence to yield the mean population dose for that source term. The same analytical process is performed to yield the offsite economic consequence.

Q48. In describing the phases of MACCS2, you mentioned mitigation measures that are modeled including evacuation, sheltering, and relocation in the emergency phase, and decontamination, temporary interdiction, and condemnation in the late phase. Please explain these measures.

A48. (KRO, GAT) The mitigative measures may be described as follows:

- *Evacuation* is used to refer to the immediate movement of individuals out of an area at the time of an accident. Evacuation may be implemented before any significant release of radioactive material occurs as a precautionary, preventive measure based on in-plant conditions.

- *Sheltering* refers to keeping individuals indoors in readily available, nearby structures for protection against exposure to an airborne plume. Sheltering may be recommended before any release of radioactive material occurs as a precautionary, preventive measure base on in-plant conditions. This measure may be performed alone or in conjunction with evacuation.

- *Relocation* is the movement of a population from an area outside the normal pre-planned evacuation zone. It is based on monitored or projected levels of radioactive contamination and subsequent radiological exposure conditions, and can be initiated in either the emergency or the late phase.

- *Decontamination* refers to the process of cleanup and restoration of land, vegetation and property in an area through measures which reduce anticipated radiological doses by removing the near-surface radioactive material through physical or chemical means or by providing shielding (*e.g.*, road repaving).

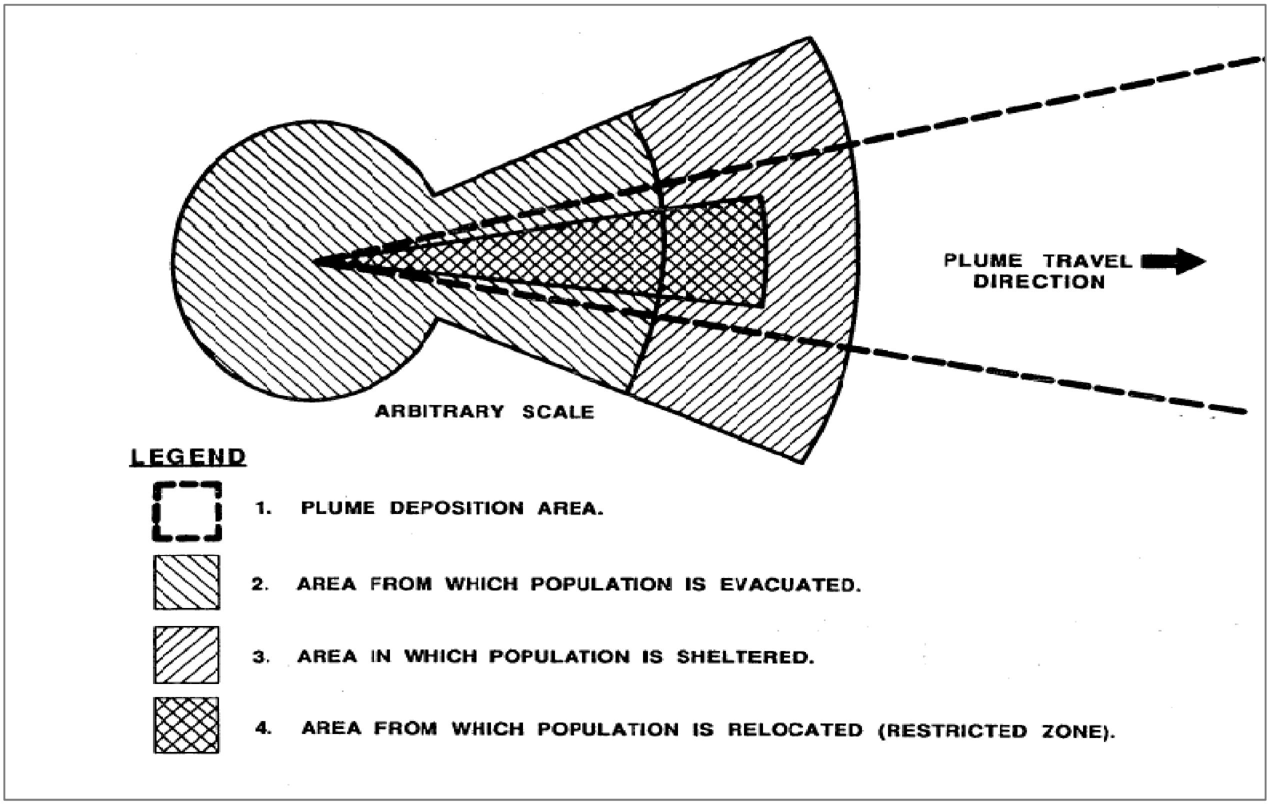
- *Interdiction* of habitability refers to the prevention of people from residing in an area for a specified time due to radiological exposure from land and surface contamination. *See* NUREG/CR-6613, Vol. 1 at 7-2 to 7-3 (NYS000243).

- *Agricultural interdiction* refers to the prevention of farming in an area and use of any agricultural foodstuffs that the land area supports. *Id.* at 7-3 to 7-4.

- *Condemnation* is the permanent interdiction in either the case of inhabiting land or using it for agricultural purposes. *Id.* at 7-9.

Q49. Generally speaking, how would the atmospheric plume travel direction and its deposition pattern influence the mitigation measures?

A49. (KRO, GAT) A generalized example is useful to illustrate how the atmospheric plume travel direction and its deposition pattern can influence potential mitigation measures that may be carried out by area in response to a radiological release. Figure 4 provides such an example of the different areas on the polar coordinate grid and the mitigation measures that potentially could be applied to a radiological release from a nuclear facility, based on protective action guidance from the Environmental Protection Agency (NYS000245A). The path of the atmospheric plume and its deposition pattern is represented by area 1. Because of plant conditions and other considerations before or after the release in this example, persons can be evacuated from area 2 and sheltered in area 3. Persons who have been evacuated from or sheltered in areas 2 and 3,



<u>**Figure 4**</u>. **Plume Deposition and Population Response Areas** (Taken from Fig. 7-1, *Manual of Protective Action Guides and Protective Actions for Nuclear Incidents*, U.S. Environmental Protection Agency (May 1992) (NYS000245A)

respectively, as precautionary actions for protection from the plume, but whose homes are outside the plume deposition area (area 1), may return to their homes as soon as environmental monitoring verifies the boundary of the area that received deposition (area 1). Area 4 is designated a restricted zone and is defined as the area where projected doses are equal to or greater than the habitability dose criterion.

In the IPEC SAMA analysis, Entergy did not credit evacuation either as part of the base-case analysis or for estimating the benefit from SAMA cases. *See* NUREG-1437, Supp. 38, Generic Environmental Impact Statement for License Renewal of Nuclear Plants, Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3, App. G at G-21 (Dec. 2010) ("FSEIS") (NYS00133I). Entergy assumed a "no-evacuation scenario" to conservatively estimate the population dose. *Id.*

The no-evacuation scenario assumes that individuals within the 10-mile evacuation zone continue normal activity following a postulated accident without taking emergency response actions such as evacuation or sheltering. *Id.* Relocation actions within a 50-mile radius of the plant were still modeled in the no-evacuation scenario. *Id.* As such, individuals within hot spots or high-radiation areas anywhere within the 50-mile zone were assumed to be relocated outside the 50-mile zone until long-term protective actions reduce radiation levels. *Id.* The NRC Staff concluded that the evacuation and relocation assumptions and analysis are generally conservative and acceptable for the purposes of the SAMA evaluation. *Id.*

Q50. In the late or long-term phase modeled in MACCS2, please describe the pathways or modes of exposure, and the mitigation actions that are modeled.

A50. (KRO, GAT) In the long-term phase, there are several modes of chronic exposure, the more important modes being direct irradiation from contaminated ground, resuspension of radioactivity and ingestion of contaminated foodstuffs. NUREG/CR-6613, Vol. 1 at 2-3 to 2-4 (NYS000243). Chronic exposure would generally involve lower dose rates than during the emergency phase, but the time scales would run from several weeks for milk ingestion and one season for crops, to 30 years or more for ground contamination to residents within the 50-mile SAMA analysis region.

There are essentially two long-term human-performed mitigation actions modeled in MACCS2: interdiction and decontamination of land, vegetation and exposed surfaces of structures, roads, etc. In addition, natural processes of weathering and radioactive decay will occur concurrently. As used in MACCS2 SAMA analysis, *weathering* is the action of weather conditions, principally precipitation and ambient wind conditions to remove and/or relocate ground and surface contamination. For example, Cs-137 deposited on surfaces from a radioactive plume may be relocated by the action of rainfall away from its original surface. Radioactive decay will decrease the areal presence of deposited radioactivity over time by the half-life of the radionuclide. The effect of weathering and decay is accounted for during the time(s) assigned to decontamination and interdiction. *See* NUREG/CR-6613, Vol. 1 at 7-3 to 7-4 (NYS000243).

During these activities, the resident population would be moved to another area, (interdiction of habitability) until the mitigation activities and, if needed, the natural processes of weathering and decay, are sufficient to meet allowed habitability criteria. *See id.* at 7-3 to 7-4.

Q51. Please describe the MACCS2 habitability model.

A51. (KRO, GAT) The return of resident populations is accounted for with a habitability model in the MACCS2 code. Habitability decision-making can result in three possible outcomes: (1) land is immediately habitable, (2) land will be habitable after decontamination, and (3) land will be habitable after a combination of decontamination and interdiction. *Id.* at 7-3 to 7-4. The outcomes are evaluated in a progressive series of steps as follows:

a. **Land Immediately Habitable.** The first step in the habitability decision-making is a determination of whether, in the absence of any mitigative actions, the land is suitable for habitation during the long-term exposure period. *Id.* at 7-3. This requires consideration of the projected individual dose calculated by the code for the long-term dose projection period (input variable TMPACT). *Id.* at 7-3, 7-5. In the IPEC SAMA analysis, this period is set to five years. Specifically, this individual dose is projected over the 5-year period and compared against a user-specified dose criterion for long-term dose (input variable DSCRLT). For the IPEC SAMA analysis, the EPA Protective Action Guideline ("PAG") of 2 rem in the first year, and 0.5 rem in the second through the fifth years, or 4 rem over the five-year interval is implemented (EPA Guidance, EPA

400-R-92-001, May 1992). This modeling approach of 4 rem over a five-year period is consistent with that employed in NUREG-1150/NUREG/CR-4551 and is consistent with most known industry MACCS2 SAMA analyses for regulatory applications. *Id.* at A-20. If the projected individual dose does not exceed DSCRLT over the dose projection period, then the land is considered immediately habitable and no further tests regarding habitability are made.

b. **Land Habitable After Decontamination.** If the land is not immediately habitable, the code evaluates a progressive series of dose reduction actions, beginning with decontamination using user-defined decontamination levels. *Id.* at 7-3. Two dose reduction processes are at work during the decontamination activity period: (1) active decontamination measures and (2) weathering and radioactive decay occurring during decontamination. *Id.* The influence of these two factors (*i.e.*, active decontamination and weathering/decay) is considered to be independent. The overall level of benefit achieved by a level of decontamination activities is specified by the dose reduction factor DSRFCT and requires a time TIMDEC to complete. The input values for DSRFCT and TIMDEC are user specified. For the IPEC SAMA analysis, the two levels of dose reduction factor are 3 and 15 and require 60 days and 120 days to complete, respectively. These pairs of inputs are based on the NUREG-1150 and NUREG/CR-4551 model and were applied in the SOARCA study.

c. **Land Habitable after Decontamination and Interdiction.** If the maximum-level decontamination effort is insufficient to allow habitability at the conclusion of the decontamination period, then the dose-reduction impacts of decontamination in combination with temporary interdiction are evaluated to determine if the habitability criterion is satisfied at the conclusion of the decontamination and interdiction periods. *Id.* at 7-3 to 7-4. As explained above, the dose reduction factor obtained from decontamination is considered to be independent of the dose reduction that results from weathering and radioactive decay. *Id.* at 7-4.

In MACCS2, the effect of weathering and radioactive decay over the interdiction period is calculated with an interpolation technique that uses pre-calculated doses for predefined interdiction periods of 1, 5, and 30 years. These periods are fixed in the code, and cannot be changed by the user. *Id.* These three predefined interdiction periods all begin at the conclusion of the maximum-level decontamination period. *Id.*

d. **Limits to Interdiction Time.** For the two separate land uses, farming and residential, the MACCS2 code will choose mitigative actions that yield the lowest-cost approach to satisfying the applicable criteria. For populations, the criteria define acceptable levels of radiation exposures to resident individuals. The maximum duration of interdiction of a population on a grid element is 30 years, and is fixed in the code. For farming, the maximum interdiction period that can be modeled is 8 years and also is also fixed in the code. If the maximum-duration interdiction of either land use is insufficient to satisfy the respective criteria for use, then that land use is assumed to be permanently interdicted or condemned. *Id.*

e. **Cost Effectiveness**. As described above, if either the farmland or the residential criterion cannot be satisfied after the maximum duration interdiction period, then the MACCS2 code will model land use as permanently interdicted, or condemned. However, the use of land for farming or for residence of a population can also be condemned if the total cost involved in restoring it to use exceeds the user-specified value of the property. If this is done, the use of land for either farm or population or both can be condemned. When a land use is condemned for either reason (*i.e.,* the dose criteria cannot be satisfied or the cost of reclamation exceeds the property's value), MACCS2 calculates the corresponding long-term food and population exposures as zero and assesses an economic cost for the condemnation of the property. *Id.*

Q52. Do NYS and Dr. Lemay focus their challenge on a particular MACCS2 module?

A52. (KRO, GAT, LAP) Yes. As discussed in Section VI below, NYS and Dr. Lemay challenge certain Entergy inputs to the CHRONC module that are related to the estimated economic costs of a postulated severe accident. ISR Report at 4 (NYS000242). They do not challenge Entergy's inputs to other MACCS2 modules.

D. <u>Description of CHRONC Economic Consequences Model in MACCS2</u>

Q53. Please describe the CHRONC module in greater detail.

A53. (KRO, GAT) The CHRONC module of MACCS2 calculates the long-term offsite population dose from contaminated areas, and contaminated food and water ingestion, due to the postulated release for the long-term phase (e.g. 30-year exposure period) following the emergency phase. NUREG/CR-6613, Vol. 1 at 7-1 (NYS000243). The population dose from groundshine, inhalation of resuspended surface contamination, and food and water ingestion are considered in this phase, along with the effects of mitigation due to protective actions. *Id.* Most relevant here, CHRONC also models the economic costs associated with both the emergency phase and the long-term phase. *Id.*

Table 1 summarizes the primary types of models used in CHRONC and examples of the input data used. For SAMA analysis, the primary input data types are the (1) dose conversion factors (*i.e.*, factors to convert exposure to radiation from different radionuclides to a unit of dose);

(2) protective action criteria (*e.g.*, sheltering and/or evacuation during the emergency phase and decontamination and interdiction during the long-term phase); (3) population distribution over a 50-mile radius spatial grid; and (4) site-related information such as land use, agricultural, and economic regional data. The outputs of CHRONC are the offsite population dose incurred during the long-term phase and economic costs of both phases of one weather sequence.

Table 1. CHRONC Module Phenomenological Models and Input Data Types

Phenomenological Model	Examples of Input Data*
Exposure pathways	Long-term pathway models are internal to the code
- Groundshine	Dose factors; shielding factors
- Resuspension inhalation	Breathing factors; shielding factors; decay constants
Food ingestion models: - MACCS model - COMIDA2 model	Ingestion model parameters (analysis performed separately and independently of MACCS2 model)
Water ingestion model	Transfer factors, land use factors
Mitigative action models	Protective action dose criteria; time factors
Economic cost model for emergency-phase	Evacuation, sheltering, and relocation cost inputs
Economic cost model for long-term phase	Decontamination, interdiction, and condemnation costs

*The listing is representative but not all-inclusive; *i.e.*, there are additional inputs to CHRONC.

As discussed below, the particular CHRONC inputs challenged or otherwise modified by NYS and Dr. Lemay relate to the economic cost model (*i.e.*, the last two rows of the above table).

Q54. For purposes of the present discussion, what are the specific decontamination-related CHRONC inputs of concern?

A54. (KRO, GAT) Table 2 lists and defines the key inputs to CHRONC relative to the issues discussed in Dr. Lemay's testimony and the ISR Report.

Table 2. **Key CHRONC Decontamination-Related and Other Economic Parameters**

	Parameter	Description of parameter	NUREG/ CR-6613, Vol. 1*
1.	VALWF	Defines the value of the farm wealth in the region in dollars per unit area. This value should include both publicly and privately owned grazing lands, farmland, farm buildings, and non-recoverable farm machinery, as well as any publicly owned infrastructure serving the farm industry.	p. 7-18
2.	VALWNF	Defines the value of the per capita nonfarm wealth in the region. Nonfarm wealth includes all public and private property not associated with farming that would be unusable if the region was rendered either temporarily or permanently uninhabitable. This value should include the cost of land, buildings, infrastructure, and the cost of any non-recoverable equipment or machinery.	p. 7-18
3.	EVACST	Defines the daily cost of compensation for evacuees and short-term relocated individuals who are removed from their homes as a result of radiation exposure during the emergency-phase period. This value could include the following components: food, housing, transportation, and lost income.	pp. 7-5 & 7-6
4.	POPCST	Defines the per capita removal cost for temporary or permanent relocation of population and businesses in a region rendered uninhabitable during the long-term phase time period. This cost is assessed if any of the following actions are required: decontamination alone, decontamination followed by interdiction, or condemnation. This value is derived in a way that takes account of both personal and corporate income losses for a transitional period as well as moving expenses.	pp. 7-13 & 7-14
5.	RELCST	Defines the daily cost of compensation for individuals removed from their homes due to intermediate-phase relocation modeled by CHRONC. The costs should include the following components: food, housing, transportation, lost income, and replacement of lost personal property.	p. 7-6
6.	CDFRM	Defines the farmland decontamination cost per unit area for each level of decontamination. Farm-dependent decontamination cost represents the cost of farmland decontamination in a spatial grid element. Farm-dependent decontamination cost is a function of the area of the grid element devoted to agriculture.	p. 7-11
7.	CDNFRM	Defines the nonfarmland decontamination cost per individual for each level of decontamination. Population-dependent decontamination represents the cost of nonfarmland decontamination. Population-dependent decontamination cost is a function of the population residing in the grid element.	p. 7-11
8.	TIMDEC	Defines the time required for completion of each of the decontamination levels.	pp. 7-10 & 7-11
9.	DLBCST	Defines the average annual labor cost of a decontamination worker.	p. 7-13
10.	DPRATE	Defines the depreciation rate that applies to property improvements during a period of interdiction. This depreciation rate is intended to account for the loss of value of buildings and other structures resulting from a lack of habitation and maintenance.	p. 7-13
11.	DSRATE	Defines the expected rate of return from land, buildings, equipment, etc. For example, the inflation-adjusted real mortgage rate for land and buildings could be used.	p. 7-13

* Exhibit NYS000243

Q55. What types of offsite economic costs are calculated in MACCS2?

A55. (KRO, GAT) The costs calculated in MACCS2 include:

- The cost of evacuation.
- The cost for temporary relocation (food, lodging, and lost income).
- The cost of decontaminating land and buildings.
- Lost return on investments from properties that are temporarily interdicted to allow contamination to be decreased by weathering/radionuclide decay.
- The cost of repairing temporarily interdicted property.
- The value of crops destroyed or not grown because they were contaminated by direct deposition or would be contaminated by root uptake; and
- The value of farmland and of individual, public, and nonfarm commercial property that is condemned.

NUREG/CR-6613, Vol. 1 at 7-9 to 7-14, 7-48 to 7-52 (NYS000243).

Q56. How does MACCS2 determine whether property should be condemned?

A56. (KRO, GAT) MACCS2 requires use of regional input economic parameters to assess whether a land element should be condemned or not. *See* NUREG/CR-6613, Vol. 1 at 7-16 to 7-20. These average regional values are the farm property value (VALWF) and the nonfarm property value ("VALWNF"). *See id.* at 7-17 & 7-18. MACCS2 evaluates potential mitigative actions for both farm land use and population habitability to determine if it is possible to satisfy the applicable criteria for radiological exposures. As discussed in A51, if either of the criteria—for farming or habitability—cannot be satisfied after the maximum duration interdiction, then that land use is permanently interdicted, or condemned. *Id.* at 7-4. Once the decision to condemn is made in the code logic, condemnation costs are incurred on a *per capita* basis for non-farmland using county-specific data and on a *per unit area (hectare)* basis for farmland.

Q57. To clarify, the economic costs calculated by MACCS2 are either population-dependent or area-dependent?

A57. (KRO, GAT) Yes. Both population- and area-dependent economic costs are calculated by MACCS2. The population-dependent costs include the sum of population-dependent decontamination, interdiction, and condemnation costs, as well as the early- or emergency-phase costs. NUREG/CR-6613, Vol. 1 at 7-9, 7-48 (NYS000243). They include:

- Population-dependent decontamination cost—nonfarm property (*i.e.*, property associated with resident population) decontamination cost. *Id.* at 7-48.

- Population-dependent interdiction cost—depreciation and deterioration of nonfarm property during the period it cannot be used during both decontamination and interdiction plus the cost of population removal (i.e. relocation). *Id.*

- Population-dependent condemnation cost—compensation paid for permanent loss of nonfarm property plus the cost of population removal (i.e., relocation). *Id.*

- Emergency phase costs —per-diem costs to compensate people for being away from home due to evacuation and relocation during the emergency phase. *Id.*

The area-dependent costs include the sum of farm-dependent decontamination, interdiction, and condemnation costs as well as milk and crop disposal costs. They include:

- Area-dependent decontamination cost—farm property decontamination cost. *Id.*

- Area-dependent interdiction cost —depreciation and deterioration of farm property during the period it cannot be used during both decontamination and interdiction. *Id.*

- Area-dependent condemnation cost —compensation paid for permanent loss of farm property because it could not be returned to production within 8 years of the accident. *Id.*

- Milk disposal costs—compensation for lost milk sales during a quarter of a year if the first year's crops require disposal.

- Crop disposal costs —compensation for lost non-milk crop sales during a full year.

Q58. Are economic costs expressed in present-day dollars?

A58. (KRO, GAT, LAP) Yes. NEI 05-01, Rev. A indicates that the economic data used in the analysis should be expressed in dollars for the year in which the SAMA analysis is being performed. NEI 05-01 at 13 (NYS000287). This enables SAMA economic costs to be compared to SAMA mitigation costs in current day dollars. To scale available economic data from a past census or survey to current conditions, NEI 05-01, Rev. A suggests the use of the ratio of the consumer price indices ("CPIs"). *Id.*

Q59. How are the MACCS2 calculations for offsite economic cost incorporated into the SAMA analysis?

A59. (KRO, GAT, LAP) The MACCS2 offsite economic cost consequence values, as well as the offsite population dose values, are multiplied by the calculated severe accident frequency results obtained from the PRA models. *See* IP-RPT-09-00044, Rev. 0, Re-Analysis of IP2 and IP3 Severe Accident Mitigation Alternatives (SAMAs) at 11 (Dec. 3, 2009) ("IP-RPT-09-00044") (ENT000459). (As we explained in A31, the first step of the SAMA analysis is to characterize the overall plant severe accident risk by developing a plant-specific PRA.) This calculation results in the key risk values of interest for determining potentially cost-beneficial SAMAs: (1) population dose risk ("PDR") in units of person-rem/year; and (2) the offsite economic cost risk ("OECR") in units of dollars/year. *Id.* The individual PDRs and OECRs for the spectrum of different accident release categories (*i.e.*, the source terms to the atmosphere for each postulated accident) are summed to determine the overall PDR and overall OECR for the SAMA analysis. *Id.*

Q60. How are the overall OECR and PDR risk metrics described above used in the actual cost-benefit evaluation that is performed as the final step of the SAMA analysis?

A60. (KRO, GAT, LAP) To identify SAMAs that may be cost-beneficial, the net value or benefit of each mitigation alternative, or SAMA, is estimated in accordance with a methodology described in NRC guidance documents and compared with the estimated cost of implementing the proposed SAMA. *See* NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook" (Jan. 1997) (ENT00010A-D); NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," Rev. 4 (Sept. 2004) (ENT000013). The results of the cost-benefit analysis of IPEC SAMA candidates are documented in NL-09-165 (ENT000009) and the Appendix G of the Staff's FSEIS (NYS00133I).

V. SUMMARY OF ENTERGY'S SAMA ANALYSIS AND MACCS2 CALCULATIONS OF OFFSITE ECONOMIC COSTS OF A POSTULATED SEVERE ACCIDENT

Q61. Did Entergy follow the guidance in NEI 05-01, Rev. A in preparing the IPEC SAMA analysis?

A61. (KRO, GAT, LAP) Yes. Entergy followed the guidance contained in NEI 05-01 in preparing its SAMA analysis. *See* NL-09-165, Attach. 1 at 3 (ENT000009). Section 5.2 and Appendix G of the NRC Staff's FSEIS contain a detailed discussion and evaluation of the IP2 and IP3 SAMA analyses, including the methods used in those analyses and the results. *See* FSEIS, Vol. 1 at 5-1 to 5-13; FSEIS, Vol. 3, App. G at G-1 to G-51 (NYS000133). Following the NEI guidance, Entergy has identified a total of 22 potentially cost-beneficial SAMAs—13 IP2 SAMA candidates and 9 IP3 SAMA candidates. *See* FSEIS, Vol. 3, App. G at G-33 and G-34.

Q62. In listing the "Total Benefit" for each SAMA, the FSEIS distinguishes between (1) Baseline Case (Internal + External Events) and the (2) Baseline Case with Uncertainty. Please explain the meaning and significance of this distinction.

A62. (LAP, KRO, GAT) In accordance with NEI 05-01 recommendations, the original SAMA analyses described in the Environmental Report (ER) included multiple cases, including a "baseline case with uncertainty" and three sensitivity cases. In particular, Entergy considered the impact that possible increases in benefits from PRA analysis uncertainties would have on the results of the SAMA assessment. The ER presents the results of an uncertainty analysis of the internal-event CDF for IP2 and IP3, which indicates that the 95th percentile value of the CDF is a *factor of 2.1* times the mean of the CDF for IP2, and a *factor of 1.4* times the mean of the CDF for IP3. Entergy assessed the impact of increasing the estimated benefits for each SAMA by these uncertainty multipliers on the SAMA results. This conservative approach follows industry practice and is tantamount to using the 95th percentile of the CDF results instead of the mean of the CDF values. *See* FSEIS, Vol. 3, App. G at G-45.

Entergy applied a multiplier of 8 to the internal-event benefits for each unit to account for both internal and external events *and* analysis uncertainty factors cited above.[2] *Id.* This approach adds conservatism to the estimated total benefit for each SAMA, to which the estimated cost of implementing that SAMA is compared. Even if they were not found to be cost beneficial in the baseline analysis, Entergy included any additional SAMAs identified as potentially cost beneficial in the uncertainty analysis within the final set of 22 potentially cost-beneficial SAMAs. NL-09-

2 As detailed in the ER and FSEIS, Entergy increased the benefit that was derived from the internal-event model by a factor 3.8 and 5.5 to account for the combined contribution from internal and external events for IP2 and IP3, respectively. The multiplier of 8 slightly exceeds the product of the external-event multiplier and the uncertainty factor for each unit; i.e., 3.80 x <u>2.10</u> = 7.98 for IP2, and 5.53 x <u>1.40</u> = 7.73 for IP3.

165, Attach. 1 at 10-28, 30-31 (Tbls. 4, 5, 6 & 7); FSEIS, Vol. 3 at G-36 to G-38 (Tbl. G-6) (NYS000133).

Q63. How was the MACCS2 code used in the IPEC SAMA analysis?

A63. (KRO, GAT, LAP) MACCS2 was used as described above to estimate the offsite population doses and offsite economic cost consequences that could result from the postulated accidental release of radioactive materials to the atmosphere during a severe accident at IPEC. *See* generally, FSEIS, Vol. 3, App. G (NYS000133). Contention NYS-12C relates to calculation of economic costs, particularly decontamination costs, using the CHRONC module of MACCS2.

Q64. What are the primary inputs to MACCS2 that Entergy used to estimate offsite economic costs resulting from a severe accident at IPEC?

A64. (KRO, GAT, LAP) As discussed previously, two primary inputs to the IPEC offsite economic cost model include population data and economic data associated with the 50-mile region surrounding IPEC.

Q65. How did Entergy develop the population input used to calculate offsite economic costs?

A65. (LAP) Entergy's population inputs are based on the projected population within the 50-mile analysis region in the year 2035. The details of Entergy's population projections are presented in Entergy's expert witness testimony on NYS-16B. *See* Testimony of Entergy Witnesses Lori Potts, Kevin O'Kula, Grant Teagarden, and Jerry Riggs on Consolidated Contention NYS-16B (Severe Accident Mitigation Alternatives Analysis) at A63-66 (Mar. 28, 2012) (ENT000003). The total estimated 2035 population was 19,228,712 persons. *Id*. at A66.

Q66. In Table 2 above, you identified a number of key CHRONC parameters. What specific values did Entergy use for those parameters in the IPEC SAMA analysis?

A66. (KRO, GAT) Entergy's specific values are listed in Table 3.

<u>Table 3</u>. Specific CHRONC Parameter Input Values Used in the IPEC SAMA Analysis

Parameter	Description	IPEC Value
VALWF	Average value of farm wealth ($/hectare) for the 50-mile radius area around IPEC.	50,071
VALWNF	Average value of non-farm wealth ($/person)	163,631*
EVACST	Daily cost for a person who has been evacuated ($/person-day)	46.7
POPCST	Population relocation cost ($/person)	8,640
RELCST	Daily cost for a person who is relocated ($/person-day)	46.7
CDFRM	Cost of farm decontamination for decontamination levels of 3 and 15 ($/hectare) [dose reduction factor shown in ( ) after value]	972 (3) 2,160 (15)
CDNFRM	Cost of non-farm decontamination for decontamination levels of 3 and 15 ($/person) [dose reduction factor shown in ( ) after value]	5,184 (3) 13,824 (15)
TIMDEC	Time required time required for completion of each of the decontamination levels (days) [dose reduction factor shown in ( ) after value]	60 (3) 120 (15)
DLBCST	Average cost of decontamination labor ($/person-year)	60,480
DPRATE	Property depreciation rate (per year)	0.20
DSRATE	Investment rate of return (per year)	0.12
* For reasons discussed below, this value was later revised to $208,838/person.		

Q67. Please describe the farmland wealth value (VALWF) used in the IPEC SAMA analysis and how Entergy developed that input.

A67. (KRO, GAT) MACCS2 requires an input of the average value of farm wealth (VALWF, expressed in dollars per hectare) for the 50-mile region around IPEC. As indicated in Table 2 above, this value defines the value of farm wealth in the region and includes both publicly and privately-owned grazing lands, farmland, farm buildings, and nonrecoverable farm machinery.

Entergy obtained county-specific farmland property values from the U.S. Department of Agriculture for 2002 and used those as a basis for deriving the input value of $50,071/hectare. Enercon, Site Specific MACCS2 Input Data for Indian Point Energy Center, Rev. 1 at 5-3 to 5-6 (Dec. 1, 2009) ("Enercon MACCS2 Report") (NYS00270A).

Q68. Please describe the value of nonfarm wealth (VALWNF) value used in the IPEC SAMA analysis and how Entergy developed that input.

A68. (GAT, LAP, KRO) The nonfarm wealth input defines the value of per capita nonfarm wealth in the region (expressed in dollars per person). Nonfarm wealth includes all public and private property not associated with farming that would be unusable if it was rendered temporarily or permanently uninhabitable. Entergy developed estimates of the nonfarm wealth value for each county (MACCS2 variable VNFRM) based upon fixed reproducible tangible wealth, a measure of the durable goods that are owned in an area. Enercon MACCS2 Input Report at 5-5 to 5-6 (NYS00270A). It obtained county specific values for nonfarm wealth data from the data set of the SECPOP2000 computer software. *Id.* at 5-5. In addition, to ensure that economic information pertaining to New York City was included in the analysis, Entergy combined the nonfarm property values for four counties within the metropolitan New York City region as a weighted average (weighted by population) and assigned it to the Queens economic region. *Id.*

An average regional value of nonfarm wealth (MACCS2 variable VALWNF) was then computed for the 50-mile radius area from IPEC for use in the MACCS2 analysis. This value was calculated as VNFRM weighted by the area that each of the 28 counties has in the IPEC 50-mile radius area. *Id.* at 5-6. The original baseline value for VALWNF calculated in this manner was $163,631/person. *Id.*

Q69. Did Entergy later modify its original baseline nonfarm wealth value?

A69. (GAT, LAP, KRO) Yes. Subsequent to this initial analysis, Entergy estimated the impact of lost tourism and business as a sensitivity case. *See* NL-08-028, Letter from Fred Dacimo, Entergy, to NRC "Reply to Request for Additional Information Regarding License Renewal Application - Severe Accident Mitigation Alternatives Analysis" (Feb. 5, 2008), Attach. 1 at 25-26 ("NL-08-028") (ENT000460); *see also* NL-08-086, Letter from Fred Dacimo, Entergy, to NRC "Supplemental Reply to Request for Additional Information Regarding License Renewal Application" (May 22, 2008) (ENT000477); FSEIS, Vol. 3, App. G at G-21, G-43, G-45 to G-46. To assess lost business, Entergy obtained measures of total economic activity by examining a suite of products related to the national Gross Domestic Product ("GDP"), which is a measure of the total value of goods and services produced in an area. NL-08-28, Attach. 1 at 25. The GDP and the analogous Gross State Product ("GSP") were estimated by the Bureau of Economic Analysis, U.S. Department of Commerce. *Id.* The Gross Metro Product ("GMP") is the metropolitan-area equivalent of GSP and was derived by Global Insight (leading economic analysis and forecasting firm) using state GSP data. *Id.* GMP is reported in Global Insight 2006 by Metropolitan Statistical Area ("MSA") or Division ("MSD") standards defined by the U.S. Office of Management and Budget.[3] *Id.*

The GDP/person values for 2004 were developed to estimate the total value of goods and services produced in the 50-mile radius area. *Id.* This essentially is all the items that were

[3] *See* "Standards for Defining Metropolitan and Micropolitan Statistical Areas," 65 Fed. Reg. 82,228 (Dec. 27, 2000) (ENT000470). MSAs are associated with at least one urbanized area, have a population of at least 50,000, and comprise a central county or counties containing the core area, plus adjacent outlying counties that are economically integrated with the central county. *Id*. at 82,238. MSDs have a core with a population of at least 2.5 million and consist of one or more main/secondary counties that represent an employment center or centers, plus adjacent counties associated with the main county or counties through commuting ties. *Id*. There are three MSDs and five MSAs within the 50-mile radius area surrounding IP2 and IP3 which include all counties within the study area except two (Litchfield, CT and Sullivan, NY). *See* NL-08-028, Attach. 1 at 25 (ENT000460).

manufactured or produced in the area in 2004, plus "services" that produce economic activity in that year. *Id.* The modified VNFRM values, therefore, were a measure of the people's nonfarm wealth as well as a measure of their economic output. *Id.*

The average value of nonfarm wealth was developed based upon the most recent and complete economic dataset available at the time of the SAMA analysis for the counties within the 50-mile radius using the modified nonfarm wealth values. *Id.* at 26. The revised estimate of average nonfarm wealth value for the full 50-mile radius region therefore was quantified as $208,838/person. *Id.*

Q70. How did Entergy derive the values of the other CHRONC inputs listed in Table 3 above?

A70. (KRO, GAT, LAP) The values of the other inputs to the MACCS2-based SAMA analysis listed in Table 3 above were derived from NUREG-1150 and its associated technical basis document, NUREG/CR-4551. NL-08-028, Attach. 1 at 37-38 (ENT000460). As explained above, NUREG-1150 documented the results of an extensive NRC-sponsored PRA that examined five plants representative of classes of reactor and containment designs to give an understanding of risks for these particular plants. *See* A35, *supra*. Surry Power Station, Unit 1, a Westinghouse PWR plant, was one of those five plants. Surry was chosen by the NUREG-1150 study team because it is representative of a large set of U.S. PWRs, and because it was studied in the landmark WASH-1400 Reactor Safety Study (a probabilistic risk evaluation) and in the 1982 Sandia Siting Study.

Q71. Did Entergy make any adjustments to the NUREG-1150 values?

A71. (KRO, GAT, LAP) The NUREG-1150 study utilized the same CHRONC economic inputs for each of the five sites, except for the variables related to farm and nonfarm wealth (*i.e.*, VALWF and VALWNF), which are based on region-specific inputs (as discussed above for IPEC).

NEI 05-01 states that data should be expressed in today's dollars (dollars for the year in which the SAMA analysis is being performed), not extrapolated to the end of the period of extended operation. NEI 05-01 at 13 (NYS000287). It further states that economic data can be converted to today's dollars using the ratio of current to past consumer price indices. *Id.* Therefore, Entergy adjusted the NUREG-1150 values (except for VALWF and VALWNF) for inflation to 2005 dollars by converting the NUREG-1150 values (from the year 1986) using the ratio of current to past consumer price indices ("CPIs"), consistent with the guidance in NEI 05-01. NL-08-028, Attach. 1 at 38 (ENT000460). The CPI for 1986 was 109.6, and the CPI for 2005 was 195.3. *See* Consumer Price Index History Table: Table Containing History of CPI-U U.S. All Items Indexes and Annual Percent Changes From 1913 to Present (ENT000461). The CPI ratio approach is consistent with that used in the SOARCA Project. *See* Draft NUREG-1935, at 61, 63 (ENT000455).

Table 4 below shows the final input parameter values, along with the corresponding values from the NUREG-1150 study (which applied the MACCS code), and the parameter ratios of the IPEC SAMA analysis to NUREG-1150 values.

Table 4. **Comparison of Decontamination and Related Economic Parameters for IPEC SAMA analysis Compared to NUREG-1150 LWR Inputs**

Index	MACCS2 Parameter	Parameter Description	IP2 and IP3 (MACCS2)	NUREG-1150 (MACCS)	(IP2-IP3)/ NUREG-1150
1	DLBCST	Decontamination worker labor cost ($/person-year)	60,480	35,000	1.7
2	EVACST	Emergency phase cost of evacuation/ relocation ($/per day)	46.7	27	1.7
3	POPCST	Per capita cost of long-term relocation ($/person)	8,640	5,000	1.7
4	RELCST	Relocation cost per person day ($/person-day)	46.7	27	1.7
5	CDFRM	Farmland decontamination cost ($/hectare), given DSRFCT as defined below	Farmland decontamination cost ($/hectare), given DSRFCT in 3rd column	Farmland decontamination cost ($/hectare), given DSRFCT in 3rd column	
	Dose Reduction Factor	DSRFCT=3	972	562.5	1.7
	Dose Reduction Factor	DSRFCT=15	2,160	1,250	1.7
6	CDNFRM	Non-Farmland decontamination cost ($/person), given DSRFCT as defined below	Non-Farmland decontamination cost ($/person), given DSRFCT as defined below	Non-Farmland decontamination cost ($/person), given DSRFCT as defined below	
	Dose Reduction Factor	DSRFCT=3	5,184	3,000	1.7
	Dose Reduction Factor	DSRFCT=15	13,824	8,000	1.7
7	VALWF	Regional Average Value of Farm Wealth ($/hectare)	50,071	2,613	19.2
8	VALWNF	Regional Average Value of Non-Farm Wealth ($/person)	208,838	84,000	2.5

Q72. Please explain why, in your professional opinion, the various MACCS2 economic parameter values listed above and used in the IPEC SAMA analysis are reasonable?

A72. (KRO, GAT) As stated above, Entergy's values for these parameters are largely derived from NUREG-1150. That study underwent two extensive peer reviews of its assessment of quantitative and qualitative PRA information on nuclear power plants of different designs with respect to severe accident sequences. To this day, NUREG-1150, and its supporting technical basis, NUREG/CR-4551, are widely regarded as seminal sources of information for Level-3 PRAs and associated cost-benefit analyses, including SAMA analyses.

As previously noted, NUREG-1150 is supported by NUREG/CR-4551, which provides the substantive technical details of the risk studies of the five nuclear power plants considered in NUREG-1150. The economic variables discussed above are described in NUREG/CR-4551. The summary discussions of those variables in NUREG-1150 reference NUREG/CR-4551.

The key MACCS2 input data that contribute to the offsite economic costs were developed from NUREG/CR-4551, Vol. 2, Rev. 1, Pt. 7 (NYS000248). The input assumptions are presented in Chapter 5 of that document. Table 5.1 and its supporting discussion provide a technical basis for economic parameter values for MACCS2 (DPRATE, DSRATE, EVACST, POPCST, RELCST, and VALWNF), while the remainder of the values (DLBCST, CDFRM, and CDNFRM) are provided in Appendix A. These NUREG/CR-4551 parameter values have been used by numerous other applicants after scaling to reflect the basis year of the SAMA analysis.

As described in NUREG/CR-4551, Section 5.2.1 (and NEI-05-01, Section 3.4.2), economic data should be expressed in today's dollars. The recommended values for these parameters in NUREG/CR-4551 are presented in 1986 dollars and, therefore, were converted by Entergy to 2005 dollars (the most recent year for which data were available for IP2 and IP3 SAMA analysis) using the CPI ratio method discussed in A71. Entergy's development of the offsite economic cost inputs, as reflected in Table 4, was fully consistent with applicable NEI guidance.

The following briefly summarizes the reasonableness of the various IP2 and IP3 values summarized in Table 4:

- <u>DLBCST</u>: Decontamination labor cost of $60,480/person-year is judged reasonable for the primarily manual labor involved in decontamination efforts (e.g., vacuum sweeping, soil scraping, roof removal, etc.)
- <u>EVACST/RELCST</u>: Relocation costs of $46.70/person-day is judged reasonable considering that relocation will typically involve households (*e.g.*, $140/day or $4,200/month for a household of three) and will involve some mass housing arrangements and some long term housing arrangements.
- <u>POPCST</u>: A value of $8,640/person primarily for lost income associated with long term relocation is judged reasonable. Once again, for a household of three, this equates to $25,920.
- <u>CDFRM</u>: Decontamination costs of farmland of $972/hectare (dose reduction factor of 3) and $2,160/hectare (dose reduction factor of 15) are judged reasonable for deep plowing and/or soil scraping of open farmland. Although the basis for the NUREG-4551 cost estimate for farm decontamination is not fully explained in that document, we know of no more appropriate decontamination data that is readily available to licensees to use in a SAMA analysis to satisfy the purposes of NEPA.
- <u>CDNFRM</u>: Decontamination costs of non-farmland of $5,184/person (dose reduction factor of 3) and $13,824/person (dose reduction factor of 15). For a household of three, this equates to $15,552 and $41,472 for dose reduction factors of 3 and 15, respectively. These

values are judged reasonable for use. Based on the pedigree of NUREG-1150 and NUREG/CR-4551 data sources, we know of no more appropriate data that is readily available to licensees to use in a SAMA analysis to satisfy the purposes of NEPA. Although other decontamination data sources may exist, and will be discussed in response to NYS's allegations, such data sources are not readily applicable in the U.S. context and are not readily assessed or amenable for inclusion in MACCS2 analyses.

- VALWF/VALWNF: Values of farm wealth ($50,071/hectare) and non-farm wealth ($208,838/person, or $636,514/family of three) were developed based on site-specific data rather than on scaling of NUREG-1150 / NUREG/CR-4551 data and are considered reasonable.

The economic cost parameters discussed above were developed based on cost assumptions related to averages developed from the regions studied by the NRC and its contractors in the NUREG-1150 study. However, these costs are reasonable for the IPEC region because the initial development of those costs included residential areas. *See* Section 4 of NUREG/CR-3673, "Economic Risks of Nuclear Power Reactor Accidents" (Apr. 1984) ("NUREG/CR-3673") (ENT000466). NUREG/CR-3673 indicates cleanup cost estimates were provided for farmland and residential, business, and public property based on feasible decontamination techniques. The study also considered large areas which may require decontamination after the worst accidents in defining the variety of decontamination techniques which could be employed. *Id*. at 4-15. Also, decontamination cost estimates incorporated information on a multitude of possible methods to be used in the decontamination of non-farm areas, and were weighted to account for residential, commercial and industrial, and public use land areas based on national average statistics. *Id.* at 4-17.

Decontamination parameters also are reasonable for the IPEC region, because established estimates of decontamination costs (such as those provided in NUREG/CR-4551) are based upon levels of contamination and population rather than upon the region in which the contamination occurs. Thus, while some areas within a 50-mile radius of IPEC have high population densities, other areas have low population densities (*e.g.*, due to the high proportions of local, state and federal parkland and other rural property).

Accordingly, we conclude that the economic cost parameters derived from NUREG-1150 and adjusted in the manner described above are reasonable for the IPEC 50-mile SAMA analysis region. Based on the pedigree of NUREG-1150 and NUREG/CR-4551 data sources, we know of no more appropriate data that are readily available to licensees and suitable for use in a SAMA analysis to satisfy the purposes of NEPA. As we explain in the following section of our testimony, NYS has provided no such data in its testimony.

Q73. Did the NRC Staff review Entergy's methodology for calculating the economic data inputs and the actual data input values used in the IPEC SAMA analysis?

A73. (KRO, GAT, LAP) Yes. The NRC Staff's review of Entergy's methodology and MACCS2 input values is summarized in Appendix G of the FSEIS. *See* FSEIS, Vol. 3, App. G (NYS00133I). The Staff concluded in its FSEIS that Entergy's methodology "provides an acceptable basis from which to proceed with an assessment of candidate SAMAs." *Id*. at G-21 to G-22. In response to issues raised in Contention NYS-12 and later amendments thereto, the Staff, with technical assistance from Sandia, performed a detailed assessment of Entergy's methodology. *Id*. at G-22. The Staff and Sandia concluded that Entergy's decontamination cost estimates are "reasonable and acceptable," and consistent with those used in SAMA analyses performed for other nuclear power plants and previously accepted by the NRC. *See id.* at G-24.

VI. <u>REBUTTAL TO NYS'S AND DR. LEMAY'S CLAIMS</u>

A. <u>Use of Generic Economic Inputs to the MACCS2 Code</u>

Q74. Please summarize the stated bases for NYS's and Dr. Lemay's claim that Entergy's use of input values contained in Sample Problem A of the MACCS2 *User's Guide* caused Entergy to underestimate the economic costs of a severe accident at IPEC.

A74. (KRO, GAT, LAP) First, Dr. Lemay claims that Entergy should have developed site-specific inputs to MACCS2, because the MACCS2 "Sample Problem A" inputs used by Entergy incorporate site-specific data for the Surry nuclear power plant in Virginia. Lemay Test. at 19-21, 61-63 (NYS000241). According to Dr. Lemay, because Surry is largely surrounded by farmland, Entergy's use of Sample Problem A inputs is inappropriate given the larger population and higher building density within the 50-mile radius region around IPEC. *Id.* at 19-21. In this regard, Dr. Lemay refers to the New York City area as a "hyper-urban" area with a "very high population density and consist[ing] mostly of high-rise buildings." *Id*. at 20.

Q75. What is MACCS2 Sample Problem A?

A75. (KRO, GAT) Section 4.0 (Installing and Running MACCS2) of the *MACCS2 User's Guide* contains six sample problems, Sample Problems A through F. NUREG/CR-6612, Vol. 1 at 4-1 to 4-9 (NYS000243). The *MACCS2 User's Guide* uses these sample problems to compare MACCS and MACCS2 (*e.g.,* the dose algorithms) and to illustrate different aspects of code functionality. *See id.* As stated in the *MACCS2 User's Guide*, Sample Problem A is based on input data used for the NUREG-1150 assessment of Surry Unit 1. *Id.* at 4-3.

Q76. As an initial matter, did Entergy rely on Sample Problem A input values?

A76. (KRO, GAT, LAP) Entergy relied on Sample Problem A values insofar as those values are based on, and coincide with, the relevant values in NUREG-1150. Entergy applied inputs that were based on the NUREG-1150 study, and it updated those input values using the CPI ratio for 1986 to 2005 (basis year for the IPEC SAMA analysis), in accordance with NEI 05-01 guidance. *See* A58 & A71, *supra*. Importantly, Dr. Lemay does not acknowledge the source and pedigree of the inputs used by Entergy. Specifically, prior to their inclusion in NUREG-1150 plant-specific MACCS/MACCS2 analyses, these input values were vetted by technical staff. As NUREG/CR-4551 explains:

> Estimation of offsite accident consequences is the customary final step in a probabilistic assessment of the risks of severe nuclear reactor accidents. Recently, the Nuclear Regulatory Commission reassesses the risks of severe accidents at five U.S. Power reactors (NUREG-1150). Offsite accident consequences for NUREG-1150 source terms were estimated using the MELCOR Accident Consequence Code System (MACCS). *Before these calculations were performed, most MACCS input parameters were reviewed, and for each parameter reviewed, a best-estimate value was recommended.* This report presents the results of these reviews. Specifically, *recommended values* and the basis for their selection are presented for MACCS atmospheric and biospheric transport, emergency response, food pathway, and economic input parameters.

NUREG/CR-4551, Vol. 2, Rev. 1, Part 7 at iii/iv (emphasis added) (NYS000248).

Q77. Please clarify the relationship between the NUREG-1150 input values and the MACCS2 *User's Guide* Sample Problem A input values.

A77. (KRO, GAT, LAP) The NUREG-1150 study was published in 1990, well before the release of MACCS2 1.13.1 (the MACCS2 version used by Entergy to determine SAMA offsite population dose and economic costs) in early 2004 or the release of the *MACCS2 User's Guide* in 1998. The *MACCS2 User's Guide* applies many of these NUREG-1150 peer-reviewed inputs to its list of sample input files, including the file used as a starting point by Entergy in its plant-specific analyses for the IPEC plants. The *MACCS2 User's Guide* (not the NUREG-1150 authors, as suggested by Dr. Lemay on pages 21-22 of his testimony) indicates that sample problems were chosen to maintain continuity with the calculation examples provided in the predecessor code MACCS 1.5.11.1. *Id.* The three sample problems distributed with versions of MACCS prior to MACCS2 are analyses of commercial nuclear reactor accident scenarios based on Surry Unit 1. *Id.* The *MACCS2 User's Guide* selection of Surry was made secondarily to illustrate implementation of the new food pathway model (COMIDA2) in analyses using random sampling of weather to account for uncertainty in weather conditions at the time of the postulated accident. NUREG/CR-6613, Vol. 1 at 4-3 (NYS000243).

In other words, Surry's application in Sample Problem A was based on many other objectives than simply "test[ing] the food chain model because it is largely surrounded by farmland." Lemay Test. at 22 (NYS000241). Furthermore, with respect to the specific CHRONC economic and decontamination input parameters in question here, NUREG-1150 used the *same* values for those parameters for each of the five study sites. *See* NUREG/CR-4551, Vol. 2, Rev. 1, Part 7, Ch. 5 & App. A (NYS000248).

Q78. What is your response to Dr. Lemay's suggestion that Entergy has improperly relied on Sample Problem A input values as "default" values in its SAMA analysis.

A78. (KRO, GAT, LAP) Dr. Lemay's suggestion is incorrect. He wrongly suggests that Entergy has arbitrarily relied upon parameter values obtained from Sample Problem A. Lemay Test. at 22, 61 (NYS000241). The use of the NUREG-1150/Sample Problem A values at issue here is standard for Level 3 PRA studies (including SAMA analyses) performed in the U.S. That fact reflects the PRA community's belief that those values have an established and appropriate technical basis that warrants their continued use in NRC-related PRA/SAMA analysis applications. Indeed, the NRC Staff has expressly stated: "Standard MACCS2 modeling for NRC assessments uses the parameters in Sample Problem A." NUREG/CR-6953, Vol. 1, "Review of NUREG-0654, Supplement 3, Criteria for Protective Action Recommendations for Severe Accidents," at 32 (Dec. 2007) (ENT000291).

Notably, this is the same approach adopted by the NRC Staff and Sandia in the context of the SOARCA project, a state-of-the-art assessment of the accident progression, radiological releases, and offsite consequences associated with a severe accident. The Summary report to the SOARCA project (Draft NUREG-1935) states:

> *Values from NUREG-1150 provide the basis for decontamination parameters, which consist of two levels of decontamination, just as in NUREG-1150*. The cost parameters associated with decontamination are adjusted to account for inflation using the Consumer Price Index. This report does not consider costs associated with a reactor accident; however, these parameters do affect decisions on whether contaminated areas can be restored to habitability and therefore affect predicted doses and risk of health effects.

Draft NUREG-1935, at 63 (emphasis added) (ENT000455).

B. Dr. Lemay's Flawed Approach to Evaluating Specific Economic Cost Inputs

Q79. Did Dr. Lemay conduct his own analysis of specific economic cost inputs to the IPEC SAMA analysis?

A79. (KRO, GAT) Yes. ISR conducted a sensitivity analysis on the MACCS2 code to determine which inputs "directly and most significantly" affect mitigation costs following a severe accident. Lemay Testimony at 23-24 (NYS000241); ISR Report at 9-10 (NYS000242).

Q80. Did you review Dr. Lemay's sensitivity analysis?

A80. (KRO, GAT) Yes.

Q81. What is a sensitivity analysis in this context?

A81. (KRO, GAT) A sensitivity analysis evaluates to what degree code outcomes or outputs are sensitive to changes in the code assumptions or inputs.

Q82. Was the sensitivity study performed by ISR a technically valid and complete approach to evaluating the important input parameters in the MACCS2 SAMA analysis?

A82. (KRO, GAT) No. While a sensitivity analysis is a technically valid approach, the ISR sensitivity analysis is not complete. Sensitivity analysis is an accepted means of identifying parameters that have a significant influence on results of interest. In MACCS2 analyses, the offsite population dose and offsite economic cost results are used to support the SAMA cost benefit evaluation process to yield the overall plant population dose risk (PDR) and offsite economic cost risk (OECR). The ISR sensitivity analysis is deficient, in that the analysis only examines the impact of parameter changes on one of the outputs (*i.e.*, OECR). The impact of parameter changes on PDR is not documented or discussed in the ISR Report or Dr. Lemay's testimony.

This omission is significant for two reasons. First, the PDR also is important in the SAMA cost-benefit evaluation. As shown in Tables 5 and 6 below (which extract data from Tables 3 and 4 of Entergy Report IP-RPT-09-00044 (ENT000459)), the PDR contributes approximately 40% to the total costs based on internal events.

Second, based on our experience as MACCS2 analysts, we note that the impacts of changes to decontamination strategies often move PDR and OECR values in opposite directions. For instance, a significant increase in the decontamination time would be expected to increase OECR (as shown in the ISR report), because the interdiction period for individuals would be longer due to per-diem costs over an extended time. However, the population dose would be expected to decrease because individuals would not return to their homes as quickly and the effects of natural decay and weathering would decrease potential groundshine and resuspension doses to returning residents. In other words, increases to the OECR (as posited by Dr. Lemay due his use of alternative CHRONC input values) will be offset to some extent by concomitant decreases in the PDR.

Table 5. **IP2 Internal Event Contributors to SAMA Analysis Benefit (Averted Costs)**

Cost Category	Present Dollar Value ($)	% Contribution
Off-site Exposure Cost (based on PDR)	1,881,355	41.4
Off-site Economic Cost (based on OECR)	2,281,735	50.2
On-site Exposure Cost	6,814	0.2
On-site Economic Cost	374,303	8.2
Total	4,544,208	100

Table 6. **IP3 Internal Event Contributors to SAMA Analysis Benefit (Averted Costs)**

Cost Category	Present Dollar Value ($)	% Contribution
Off-site Exposure Cost (based on PDR)	2,040,646	40.1
Off-site Economic Cost (based on OECR)	2,809,117	55.1
On-site Dose	4,377	< 0.1
On-site Economic Cost	240,475	4.7
Total	5,094,615	100

Q83. Putting aside the oversight discussed above, what were the results of ISR's sensitivity analysis?

A83. (KRO, GAT) ISR determined that decontamination costs are the dominant factor in the evaluation of the remediation costs following a severe accident. Lemay Test. at 27 (NYS000241); ISR Report at 13 (NYS000242). ISR concluded that the most sensitive input parameters related to decontamination costs include: (1) decontamination factor (DF); (2) nonfarm decontamination cost; (3) decontamination time; (4) value of nonfarm wealth; and (5) per capita cost of long-term relocation. Lemay Test. at 27.

Q84. For what CHRONC parameters does Dr. Lemay propose alternative values in the ISR Report?

A84. (KRO, GAT) Dr. Lemay proposes his own values for the following parameters:

- Cost of non-farm decontamination (CDNFRM) for DRF =3 and DRF = 15
- Decontamination time (TIMDEC) for DRF =3 and DRF = 15
- Value of nonfarm wealth (VALWNF)
- Relocation costs (POPCST)
- Depreciation rate (DPRATE)
- Societal discount rate of property (DSRATE)
- Nonfarm wealth improvements fraction (FRNFIM)

As discussed further below, the substantially larger offsite economic costs calculated by Dr. Lemay are due principally to his proposed alternative values for the decontamination time (TIMDEC) and nonfarm decontamination cost (CDNFRM) parameters in MACCS2.

C. Discussion of Specific MACCS2/CHRONC Inputs Cited by NYS

1. Decontamination Factor (DF) and Dose Reduction Factor (DRF, or DSRFCT)

Q85. Let's discuss each of the input parameters mentioned above, beginning with decontamination factor. What does a decontamination factor measure?

A85. (KRO, GAT) A decontamination factor ("DF") is generally defined as the ratio between the contamination levels before and after decontamination has been performed. Specifically a DF represents the efficiency of removing activity from a particular surface. *See*, *e.g.*, EPA Technical Brief, "Evaluation of Five Technologies for the Mechanical Removal of Radiological Contamination from Concrete Surfaces" at 2 (Mar. 2011) (NYS000261); Thiessen *et al.*, "Modeling remediation options for urban contamination situations" 100 J. Env. Rad. 564, 568 (2009) (ENT0000462).

Q86. What values did Entergy use for DF in the IPEC SAMA analysis?

A86. (KRO, GAT) As an initial matter, Entergy did not use any DFs as inputs in the MACCS2 IPEC SAMA analysis. Although Dr. Lemay refers to Entergy's purported use of DFs, his use of that terminology is not precise or consistent with the applicable MACCS2 terminology. Specifically, the inputs applied in the MACCS2 code to evaluate decontamination, countermeasures such as interdiction, and economic consequences are termed *dose reduction factors* ("DRFs") rather than decontamination factors. *See* NUREG/CR-6613, Vol. 1 at 7-9 to 7-10 (ENT000243). In MACCS2, the relevant code input parameter is DSRFCT, which is defined as "the effectiveness of the various decontamination levels in *reducing dose*." *Id.* at 7-11 (emphasis added).

The DRF is the ratio of the radiological dose (typically 1 meter above the surface) before the remediation activity to the dose after the remediation activity. A dose reduction factor of 3 means that the resulting population dose at that location will be reduced to one-third of what it would be without decontamination activity. *Id.* In other words, the DF is a measure of the efficiency of removing radioactivity from a surface, whereas the DRF generally refers to the reduction in dose levels following an application of a countermeasure. For example, applying a clean layer of soil to a contaminated soil/grass surface will potentially yield a larger DRF than the DF, because the radioactivity (i.e., the contamination) is still present, but the dose is reduced due to the shielding effect of the new soil.

Q87. Is this important distinction reflected in the *MACCS2 User's Guide*?

A87. (KRO, GAT) Yes. The *MACCS2 User's Guide* states: "The objective of decontamination is to reduce projected doses below the long-term dose criterion in a cost-effective manner." NUREG/CR-6613, Vol. 1 at 7-9 (NYS000243). It further explains that:

> The decontamination plan data block defines the decontamination actions that may be taken during the long-term period to reduce doses

> to acceptable levels. These data define the decontamination strategies that are possible, their effectiveness, and their cost. Each decontamination level represents an alternative strategy that would reduce the projected long-term groundshine and resuspension doses by a factor called the "dose reduction factor."

Id. As noted above, the relevant MACCS2 input parameter is DSRFCT.

Q88. What dose reduction factors did Entergy used in the IPEC SAMA analysis? And why?

A88. (KRO, GAT) Entergy used dose reduction factors of 3 and 15 (*i.e.*, DSRFCT = 3 and 15) in the IPEC SAMA analysis. The values are consistent with the values used in NUREG-1150 for each of the five plants evaluated in that study. NUREG/CR-4551, Vol. 2, Rev. 1, Part 7, App. A at A-20 (NYS000248). The NRC and Sandia also applied the same DRFs (3 and 15) in the SOARCA project. *See* Draft NUREG-1935 at 62 ("Values from NUREG-1150 provide the basis for decontamination parameters, which consist of two levels of decontamination, just as in NUREG-1150.") Thus, the DRF values used by Entergy have long been judged appropriate—and continue to be judged appropriate—for use in PRA applications, including SAMA analyses.

Q89. In his testimony (page 29), Dr. Lemay indicates that "decontamination of an entire building to a level greater than 10 may not be possible without complete demolition and disposal in a licensed burial facility." What is the apparent basis for this statement?

A89. (KRO, GAT) As support for this statement, Dr. Lemay relies on three documents related to decontamination activities that were published subsequent to the Chernobyl accident: (1) the Sandia *Site Restoration Report* (NYS000249); (2) CONDO: Software for Estimating the Consequences of Decontamination Options, Report for CONDO Version 2.1 (NRPB-W43) (May 2003) (NYS000250) ("CONDO"); and (3) Practical Means for Decontamination 9 Years after a

Nuclear Accident, Risø National Laboratory (Risø-R-828(EN)) (December 1995) (NYS000251) ("Risø Report").

Q90. Do you agree with Dr. Lemay's conclusion?

A90. (KRO, GAT) No. We find this conclusion to be overly pessimistic and attributable to the following three aspects of the ISR analysis. First, Dr. Lemay's conclusion relies heavily on Sandia's *Site Restoration Report* (NYS000249). The *Site Restoration Report* was developed for estimating costs associated with the remediation of a plutonium dispersal event. Cleanup of a plutonium dispersal event differs in significant respects from cleanup of fission products from a severe reactor accident. One important difference is that Pu-239 is primarily an alpha emitter, the presence of which can be difficult to identify in the field. General area surveys cannot be conducted for the plutonium isotopes unless specialized equipment and specially trained personnel are available. *See* U.S. Environmental Protection Agency, *OSC Radiological Response Guideline*, at 101-103 (Oct. 2006) (ENT000463).

Pu-239 is primarily an inhalation hazard with a relatively long half-life of approximately 24,000 years. *See id.* at 101. Thorough removal of Pu-239 contamination is required because of the potential for subsequent resuspension and inhalation for centuries to come. Physical removal of plutonium requires significant planning for the use of respiratory protection because of the high dose that can be caused by alpha deposition inside the body. *Id.* at 103. The *Site Restoration Report* thus assumes that any area requiring a DF greater than 10 would require complete demolition. The *Site Restoration Report* states this assumption as it applies to "Expedited Decontamination of Mixed-Use Urban Areas":

> It would be impossible to ensure that particles of plutonium had not lodged within the structure, from which they could be dislodged by later housecleaning or remodeling. Complete demolition, although not the only possible strategy, appears to be the most reliable. In the scenario we

> selected for the most heavily contaminated areas, all structures would be demolished. Streets would be torn up and above ground utilities would be removed. All land surfaces would be scraped to an average depth of 10 centimeters, and clean soil would be returned.

Site Restoration Report, App. F at F-18 (NYS000249). Thus, the *Site Restoration Report* is concerned with achieving high assurance of *removing* the health hazard of Pu-239.

In contrast, the decontamination required for a major reactor accident is primarily concerned with *dose reduction* of Cesium-137 (Cs-137). Cs-137 is a gamma emitter, so it is primarily an external health hazard. *See OSC Radiological Response Guideline*, at 83-86 (ENT000463). As a gamma emitter, identification in the field is more readily performed. *Id.* at 84-85. The *Site Restoration Report* specifically recognizes this fact:

> [T]he high-energy gamma radiations emitted from deposited radioactive cesium are easily detected with simple field instruments, even if the material migrates below surfaces. In contrast, plutonium measurement in the field might be very difficult, particularly if some of the material was lodged in crevices, under vegetation, or inside buildings. Decontamination [for plutonium] would probably be useless unless the post-cleanup level of residual contamination could be reliably quantified.

Site Restoration Report, App. E at E-12. Of primary importance is the need to reduce the *dose* associated with Cs-137 to acceptable levels. In some cases, this can be accomplished using techniques such as deep plowing (*i.e.*, turning the surface land over such that it is covered by the clean soil below the surface) for open land areas.

Q91. What is the second reason for your finding that Dr. Lemay's conclusion is overly pessimistic?

A91. (KRO, GAT) As mentioned above, Dr. Lemay does not clearly distinguish between DF and DRF, which are two related but fundamentally different terms used in connection with radiological decontamination. Radiological remediation may involve removing deposited contaminants or, alternatively, leaving those contaminants in place but reducing the dose associated with those contaminants (*e.g.*, by burying the contaminants). Removing contaminants will be reflected in both the DF and the DRF, but remediation actions like burying contaminants or sealing a road will only be reflected in the DRF. The DF for such remediation actions that do not physically remove the contamination remains a value of 1.0.

The CONDO Report and Risø Report relied upon by ISR equate the decontamination factor (DF) with the removal of contaminants, not (non-removal) measures aimed strictly at reducing dose. The CONDO Report defines DF as "the (dimensionless) ratio between the amount of activity present before implementation of the decontamination technique to that following its implementation." CONDO Report at 7 (NYS000250). The Risø Report defines DF as "the concentration of the original contamination on a surface or in an object relative to what is left after a decontamination procedure." Risø Report at 6 (NYS000251).

In contrast, MACCS2 applies the DRF definition, which focuses on reducing projected doses below the long-term dose criterion. In fact, in discussing the CHRONC variable DSRFCT, the MACCS2 *User's Guide* states that this variable: "Defines the effectiveness of the various decontamination levels in reducing the dose. A dose reduction factor of 3 means that the resulting population dose at that location will be reduced to one-third of what it would be without decontamination." NUREG/CR-6613, Vol. 1 at 7-11 (NYS000243). Thus, when Entergy enters values in the MACCS2 CHRONC input file (for the IPEC SAMA analysis) for the decontamination effectiveness that is achieved for a given cost, it is entering a DRF, *not* a DF.

Q92. What is the third reason for your finding that Dr. Lemay's conclusion is overly pessimistic?

A92. (KRO, GAT) Dr. Lemay failed to consider other pertinent Chernobyl remediation data, which show that DRFs of 15 used in Entergy's MACCS2 runs are achievable. The IAEA report cited by Dr. Lemay, *Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience*, Report of the Chernobyl Forum Expert Group Environment (Apr. 2006) ("IAEA Report") (NYS000263) summarizes decontamination experiences following the Chernobyl accident. Section 4.2.2 of that report states:

> Large scale decontamination was performed between 1986 and 1989 in the cities and villages of the USSR most contaminated after the Chernobyl accident. This activity was performed usually by military personnel and included washing of buildings with water or special solutions, cleaning of residential areas, removal of contaminated soil, cleaning and washing of roads, and decontamination of open water supplies…. In total, about one thousand settlements were treated; this included cleaning tens of thousands of residences and public buildings and more than a thousand agricultural farms…
>
> Depending on the decontamination technology used, the dose rate over different measured plots was reduced by a factor of 1.5 to 15.

IAEA Report at 73-74. Thus, even in the Chernobyl experience, DRFs of up to 15 were achieved without resorting to demolition. In addition, Section 4.2.3 of the IAEA report details recommended decontamination technologies applicable to urban surfaces and presents achievable factors for dose rate reduction, reproduced in Table 8 below.[4]

Table 7. Achievable Decontamination Factors For Various Urban Surfaces (from IAEA Report, Table 4.4 (NYS000263))

Surface	Technique	Dose Rate Reduction Factor (DRRF)
Windows	Washing	10
Walls	Sandblasting	10-100
Roofs	Hosing and/or sandblasting	1-100
Gardens	Digging	6
	Removal of surface	4-10
Trees and shrubs	Cutting back or removal	~10
Streets	Sweeping and vacuum cleaning	1-50
Streets (asphalt)	Lining	>100

4 Although the table title refers to "achievable decontamination factors," the far right column clearly shows values as DRFs, rather than DFs.

In view of the Chernobyl-based experience and data discussed above, we find use of a MACCS2 input value for DRF of 15 in the IPEC SAMA analysis to be reasonable.

2. Decontamination Time (TIMDEC)

Q93. What is the decontamination time (TIMDEC) parameter in MACCS2?

A93. (KRO, GAT) The decontamination time (TIMDEC) parameter input to MACCS2 defines the time required for completion of each of the user-selected decontamination levels (*i.e.*, DRF = 3 and DRF = 15 in the case of the IPEC SAMA analysis). NUREG/CR-6613, Vol. 1 at 7-10 (NYS000243).

Q94. What values did Entergy use for decontamination time in its MACCS2 SAMA analysis?

A94. (KRO, GAT) The MACCS2 code requires users to input a decontamination time for each level of decontamination effectiveness modeled. Thus, with two levels modeled in the IPEC SAMA analysis, two decontamination times are required: one for the lower DRF, and one for the higher DRF. Entergy used an input of 60 days for a DRF of 3 and 120 days for DRF of 15. Entergy Calculation No. IP-CALC-09-00265, Rev. 0, "Re-analysis of MACCS2 Models for IPEC," Attach. A.1 at 38 & Attach. A.2 at 38 (Dec. 2, 2009) (ENT000464).

Q95. Why did Entergy select the values of 60 days and 120 days?

A95. (KRO, GAT) The two dose reduction factors (DRF = 3 and DRF = 15) and the associated decontamination times (60 and 120 days) used in the IPEC SAMA analysis are fully consistent with the NUREG-1150 values for those MACCS2 parameters. As discussed above, standard MACCS2 modeling for NRC assessments uses the NUREG-1150 input values because they have a well-established pedigree within the PRA community, having been developed and peer reviewed beginning in the early 1980s. Indeed, the use of these DRF and TIMDEC values by NRC and Sandia continues to this day in the SOARCA project. We will explain the origin and appropriateness of the 60-day and 120-day values later in our testimony.

Q96. What was ISR's assessment of the decontamination time inputs used by Entergy in the IPEC SAMA analysis?

A96. (KRO, GAT) Dr. Lemay concluded that Entergy's inputs are "unreasonable" in view of the Chernobyl and Fukushima accidents. Lemay Test. at 54 (NYS000241). He states that decontamination of the area affected by the Chernobyl accident took four years and included the decontamination of tens of thousands of buildings in the most contaminated cities and villages of the former USSR. *Id.* at 52, 54. With respect to Fukushima, Dr. Lemay notes that "some estimates suggest that the decontamination could last for decades." *Id.* at 53.

Q97. How did ISR use decontamination time information related to the Chernobyl and Fukushima events?

A97. (KRO, GAT) ISR identified a decontamination time range of 2 to 15 years for a DF of 3, and a range of 4 to 30 years for a DF of 15 and substituted these significantly larger alternative values for Entergy's TIMDEC inputs of 60 and 120 days. ISR Report at 24-25 (NYS000242).

Q98 Does the MACCS2 source code impose any limitations or restrictions on the decontamination time input values that may be entered into the code?

A98. (KRO, GAT) Yes. MACCS2 limits decontamination times to a *maximum of one year*. However, Dr. Lemay modified the FORTRAN source code in MACCS2 to allow for greater TIMDEC values. ISR Report at 24 (NYS000242).

Q99. In your opinion, is it reasonable to expect individual users of the code, including license renewal applicants, to make source code modifications when using MACCS2 or other NRC-accepted computer software to accommodate out-of-range inputs to support risk analysis applications such as SAMA analyses?

A99. (KRO, GAT) No. Risk analysis computer codes used for NRC regulatory applications such as a SAMA analysis are complex software packages that are configuration controlled. Any modifications to such codes would be expected to be performed only by experienced programming professionals using appropriate process controls and testing, and in most cases, are permissible only by the code developer. Individual license renewal applicants would not be expected to have both the authority and the requisite expertise. Applications of the MACCS2 code require all users, including individual licensees such as Entergy, to apply the computer code using allowed ranges of input parameters. An expectation to change the source code as needed is not reasonable or appropriate. Individual users must use the computer code as provided by the distributor (in this case the NRC and Sandia National Laboratories) to ensure quality assurance is maintained. If computer code models such as MACCS2 are internally altered, then configuration control is nonexistent, and standardization and consistency have been lost such that the results are no longer reliable.

(KRO) Notably, in the Pilgrim license renewal proceeding, in which I testified as an expert witness for Entergy, the Commission stated that "[t]he NRC uses MACCS2 to evaluate the potential offsite consequences of severe nuclear reactor accidents, and NRC-endorsed guidance [NEI 05-01, Rev. A] on SAMA analysis endorses use of the MACCS2 code. *Entergy Nuclear Generation Co. & Entergy Nuclear Operations, Inc.* (Pilgrim Nuclear Power Station), CLI-12-01, 75 NRC __, slip op. at 3 (Feb. 9, 2012). The NRC has provided no indication that it expects or encourages licensees to modify the code for purposes of a SAMA analysis. In the Pilgrim proceeding, the Commission stated that the intervener's demand that the MACCS2 code be rewritten to contain a different plume model "goes far beyond NEPA requirements," and that "NEPA does not require the NRC to engage in an extensive revision of the MACCS2 code." *Id.* at 29.

Q100. Do you have any concerns about ISR's modification of the MACCS2 source code to facilitate its analysis?

A100. (KRO, GAT) Yes. ISR has generated a significant software configuration control nonconformity. The standard nondisclosure agreement ("NDA") accompanying distribution of the MACCS2 code states that if changes are made they need to be communicated to the NRC and that the modified code needs to be referred to other than "MACCS2". In the case of Dr. Lemay's testimony and the ISR Report, the results were originally reported as if they were from the configuration controlled version 1.13.1 of MACCS2.

NYS or ISR provides no evidence showing that an independent review, including appropriate testing, was performed to confirm that ISR's MACCS2 source code modifications did not unintentionally result in unwanted changes elsewhere in the code. In addition, many of the MACCS2 inputs related to decontamination are correlated and cannot be changed individually without concomitant effects on other variables that could lead to inconsistencies in the output. Thus, any adjustment of a time-related variable such as TIMDEC must be considered in concert with other variables that influence the MACCS2 decontamination/interdiction model.

ISR-modified MACCS2 software output files supporting Dr. Lemay's analysis and disclosed by NYS appear to indicate that errors have resulted in the code execution. A text file titled "ISR MACCS2 Runs.txt" supplied with the ISR generated MACCS2 output files includes the following statement indicating that "FORTRAN compilation complications" occurred that impacted the ability to produce results for all source terms:

> Also important to note: for the ISR-modified MACCS2 code (i.e. ip###.out files), due to what is assumed to be FORTRAN compilation complications, only the costs of the first 7 of the 8 release modes/categories were calculated by MACCS2. ISR calculated the cost of mode 8 by multiplying the cost of mode 7 by 0.855, which was the factor between mode 7 and mode 8 in all cases using the originally-compiled MACCS2 code.

The errors raise questions as to the accuracy of the results achieved with the modified MACCS2 and exemplifies the challenge of modifying source code.

In short, based on our experience with computer codes, telltale signs of error in the output file can be indications that other functions of the computer software have been corrupted. Further, as noted above, it is not reasonable to expect license renewal applicants to modify the MACCS2 source code for purposes of performing SAMA analysis to comply with NEPA requirements.

Q101. In a February 17, 2012, declaration, Dr. Lemay stated that the MACCS2 source modifications made by ISR are "were simple and obvious for an experienced nuclear analyst." Do you agree?

A101. (KRO, GAT) No. MACCS and its successor, MACCS2, are long-established, NRC-accepted computer codes, dating from the 1980s, for preparation of PRAs and related applications, including DOE safety basis authorization support. As such, software originators and their sponsors have customarily applied an overarching review process to ensure software modifications were correctly implemented. When this process is not followed, the result is a lack of quality assurance and code errors. *See* Defense Nuclear Facilities Safety Board, Technical Report 25, "Quality Assurance for Safety-Related Software at Department of Energy Defense Nuclear Facilities" (Jan. 2000) (ENT000465). Accordingly, MACCS2 code modifications are not "simple and obvious," and thorough, independent checks of the potential effects of code modifications are warranted. As discussed in A99-A100, it is our technical judgment that it is not reasonable or appropriate for individual users to modify the MACCS2 source code for purposes of a supporting a SAMA analysis. Indeed, the NRC considers the configuration-controlled version of MACCS2 to be the standard code for such analyses. In this context, it is unacceptable from a software quality assurance context to require or expect individual users to tailor the source code to fit individual preferences.

Q102. Putting aside your concerns related to Dr. Lemay's code modifications, are the alternative decontamination time values proposed by Dr. Lemay reasonable and appropriate for use in the IPEC SAMA analysis?

A102. (KRO, GAT) No. The alternative decontamination time values proposed by ISR are not reasonable or appropriate for use in the IPEC SAMA analysis. In short, Dr. Lemay fails to properly distinguish decontamination activities that are modeled by the MACCS2 variable TIMDEC as compared to other dose reduction strategies utilized by MACCS2, such as extended interdiction. Furthermore, by proposing TIMDEC values that range from 2 to 30 years, Dr. Lemay seeks to include decontamination activities that need not be included in TIMDEC.

In MACCS2, the variable TIMDEC represents the time period during which persons are temporarily interdicted (*i.e.*, away from their residence) while decontamination activities are completed to reduce the dose by the specified dose reduction factors (*i.e.*, DRF = 3, DRF = 15). Once the time period modeled by TIMDEC is completed, MACCS2 models the relocation of persons back to their residences if the specified habitability criteria are satisfied. Thus, TIMDEC establishes the minimum time that an individual is relocated due to protective action guides.

If the habitability criteria are not satisfied following decontamination activities, then MACCS2 models an extended interdiction period, if natural decay and weathering are projected to provide sufficient additional dose reduction to satisfy the habitability criteria. The need for this additional interdiction period, which may be as long as 30 years for residential interdiction, is evaluated for each spatial grid element in the 50-mile region that is impacted by the postulated release. Thus, in MACCS2 code execution, individuals may be relocated from their property for a maximum period of TIMDEC plus 30 years. If the combination of decontamination and extended remediation cannot result in dose reduction sufficient to meet the habitability criteria, then the land is deemed condemned. In addition, if the cost of performing the decontamination strategies exceeds the value of the property, then the land is condemned.

Forcing a long decontamination period (*e.g.*, beyond a year) in the MACCS2 analysis via the variable TIMDEC, as proposed by Dr. Lemay, distorts the dose reduction resettlement optimization strategy inherent in MACCS2. Because MACCS2 will not relocate individuals back to their residences until TIMDEC expires, a long TIMDEC period may prevent the appropriate modeling of populations returning to their residences following decontamination activities. For example, if a value of 10 years is used for TIMDEC, MACCS2 will not return *any* impacted individuals to their residences until 10 years has passed. This is not appropriate for the modeling of a severe accident event in the 50-mile SAMA region around a plant. Many of the residents in this region will be able to return to their residences after a modest level of decontamination activities.

Historical experience involving long-term decontamination activities also suggests that, in some cases, decontamination activities may be continued for isolated locations (*e.g.*, public buildings such as schools) following the return of individuals to their residences. IAEA Report, Section 4.2.2, at 74 (NYS000263). Although these continuing decontamination activities are not explicitly addressed in MACCS2 modeling, they are not in conflict with MACCS2 modeling. Even when individuals have returned to their communities and residences, decontamination activities may continue in their communities for selected locations.

Q103. Are input data for the economic/decontamination model in MACCS2 simply changed one at a time without resulting in an inconsistency in the model or its output?

A103. (KRO, GAT) No. The MACCS2 code implements a decontamination/interdiction model in which a set of input parameters must be applied in concert for the cost/benefit and protective action guide logic to perform correctly. Thus, single values cannot be altered unilaterally. MACCS2 uses the time period TIMDEC to calculate per-diem expenses for those interdicted persons, and to calculate the dose associated with workers who are performing the decontamination activities. NUREG/CR-6613, Vol. 1 at 7-10 (NYS000242). In other words, if a user wants to evaluate how economic costs change with longer decontamination activity times, increasing the value of TIMDEC will not directly increase the costs associated with physical decontamination activities. For residential decontamination, the costs associated with physical decontamination activities are included in the variable CDNFRM and are not time-dependent. Rather, they are "a function of the population residing in the grid element." *See id.* at 7-9. Thus, if the user extends TIMDEC, then the costs associated with physical decontamination activities do not increase. Instead, the costs captured by CDNFRM are just effectively spread out over a longer time frame. The increase in the offsite economic costs (and in turn, the offsite economic cost risk, OECR) calculated by ISR based on very large TIMDEC values are due to the costs associated with per-diem expenses for all impacted individuals for these long time frames. In essence, ISR's approach—which again requires modification of the MACCS2 source code—constitutes an intentional defeating of MACCS2 decontamination optimization model.

To summarize, MACCS2 modeling may result in individuals being relocated for long periods of time (*i.e.*, up to TIMDEC plus 30 years). The MACCS2 user does not need to force a long TIMDEC period to accomplish an extended period of interdiction. Additionally, a long

TIMDEC period defeats timely population resettlement as would be appropriate for many individuals impacted by modest contamination levels, and where projected doses meet the protective action guides. Finally, the likelihood that certain residual decontamination activities may persist for years is not in conflict with use of TIMDEC period of 60 to 120 days. Such activities may continue (and have continued in actual experience) following population resettlement. TIMDEC seeks only to model the minimum time prior to population resettlement.

Q104. Returning to Entergy's assumptions, why are the TIMDEC values (60 and 120 days) used in the IPEC SAMA analysis reasonable and appropriate for such an evaluation?

A104. (KRO, GAT) Above, we explained why ISR's proposed decontamination times are unreasonable and fundamentally inconsistent with the MACCS2 decontamination and interdiction model. Now, we will explain why Entergy's values are reasonable and appropriate for such an analysis. This requires some detailed technical and historical discussion of the MACCS2 decontamination and interdiction models.

Q105. In discussing the MACCS2 habitability model in A51, you also discussed the manner in which MACCS models decontamination. Please describe the historical basis for the decontamination model implemented in MACCS2.

A105. (KRO, GAT) The MACCS2 decontamination/economic models are based on a *staged implementation* of offsite population protective measures in post-accident situations, and account for decontamination activities that correspond to a decontamination level that is both cost-effective and feasible. This sequence was initially outlined in the WASH-1400 model, later extended by NUREG/CR-3673 (ENT000466), and applied in both the NUREG-1150 and SOARCA studies through the use of the MACCS and MACCS2 computer codes.

The modeling of staged protective measures implementation is used to provide reasonable estimates of the costs of post-accident population-protective measures. NUREG/CR-3673 at 4-6. The projection of likely doses over multiple time periods accounts for the durations of protective measures that may be necessary for short- and long-lived radionuclide releases. *Id.* The staged implementation of offsite protective measures after severe reactor accidents is considered reasonable because full information would not be immediately available in post-accident situations, and radiological conditions in the environment may change rapidly with time. *Id.*

A generalized timeline of protective measure implementation after the start of a postulated severe accident sequence helps describe the staged protective action implementation plan based on plume deposition, decontamination efforts, economic costs, and the applied EPA Protective Action Guide criteria. As shown in Fig. 6, individuals living near and in the 10-mile emergency planning zone ("EPZ") around the reactor would be advised of potential releases, and may begin evacuation after the start of an accident sequence but prior to any release of radioactive material from the plant to the environment. Upon release of radioactive material to the environment, radiation monitoring teams will begin the task of collecting dose rate information from surface-deposited contamination. This action is likely to occur within hours of any significant release of radioactive materials. MACCS2 calculates projection of individual doses during the "emergency phase" period to account for the costs of temporarily relocating individuals in addition to those initially evacuated. The "emergency phase" relocation criterion is based on dose rate projections of short-term individual doses from exposure to surface-deposited radionuclides. NUREG/CR-6613, Vol. 1 at 2-2 (NYS000243).

As improved information becomes available concerning areas affected by a release of radioactive material, individuals initially evacuated could be allowed to return to areas not impacted. After improved information becomes available concerning dose rates in affected areas and the decay of surface deposited radionuclides with time, a second projected individual dose may be used to determine those areas where high dose rates prohibit reentry of the population. This period can be considered an "intermediate phase" of protective action implementation in the model. *Id.* at 7-1 to 7-2. A projected individual dose from groundshine and resuspension pathways during this period is compared to a criterion for continued relocation from impacted areas. *Id.* at 7-1. After time is available to more accurately determine the radiological conditions in affected areas, a projected long-term phase individual dose from exposure to surface-deposited materials is used to determine those areas which require decontamination or interdiction.

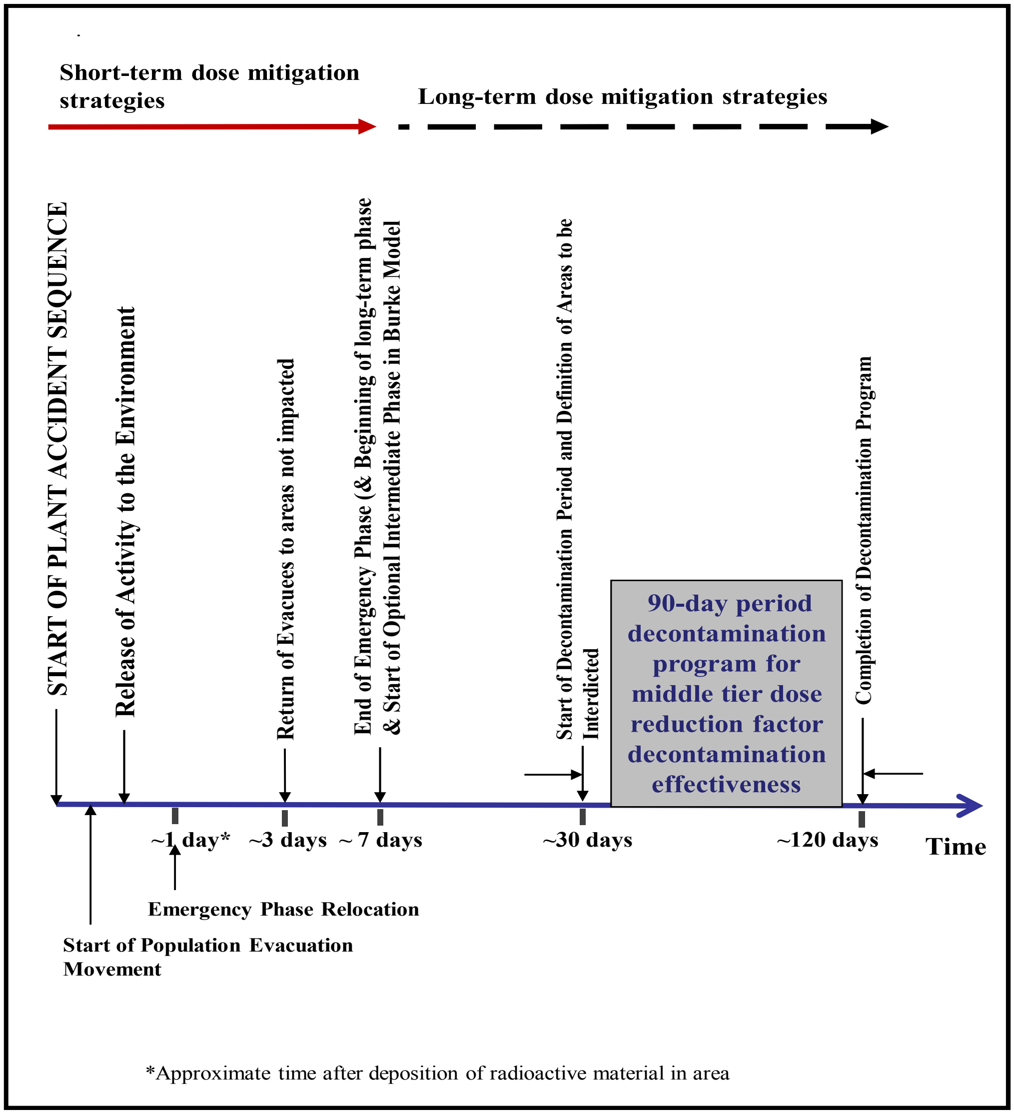


Figure 5. **Staged Protective Action Implementation Model (Based on Fig. 4.2 of NUREG/CR-3673)**

Interdiction costs are estimated for those areas where decontamination efforts cannot reduce dose rates to acceptable levels. *Id.* at 7-4.

For the decontamination plan model applied first in NUREG/CR-3673 and subsequent PRA-based analyses (including the IPEC SAMA analysis), the dose reduction factors and period of time over which they are applied would be equal in the case of farmland and non-farmland decontamination. However, the decontamination strategy, the selection of decontamination procedures, and the costs would differ for the two property types. In the original timeline portrayed in Figure 4.2 of NUREG/CR-3673 and recreated here in Figure 5, the decontamination period extended 90 days (Start of Decontamination Period (at t ≈ 30 days) to Completion of Decontamination Program at (t ≈ 120 days)). *See* NUREG/CR-3673 at 4-5 (Fig. 4.2 – Staged protective action implementation model used for estimating offsite costs) (ENT000466). Based on our interpretation of the NUREG/CR-3673 model, this is an average duration of time over which an integrated set of decontamination activities would be performed to yield a dose reduction factor of 15. The set of decontamination activities would be different based on whether the decontamination activities are applied to a population-dependent (non-farmland) area, or to an agricultural area.

Table 4.4 of NUREG/CR-3673 shows the non-farm area decontamination costs and effectiveness values used in the economic model described in that document. Based on our review of NUREG/CR-3673, including Figure 4.2 and Table 4.4, we conclude that the NUREG/CR-3673 decontamination plan's logic included shorter and longer periods with lower and higher effective dose reduction factors.

Table 8 below assembles information from NUREG/CR-3673, Table 4.4, along with example times required for completion of each of the decontamination levels from early (1987) MACCS code user's guide documentation NUREG/CR-4691 (SAND86-1562) Sandia National Laboratories, MELCOR Accident Consequence Code System (MACCS Version 1.4), Volume I, User's Guide, (Draft Version) (Revised July 15, 1987) ("NUREG/CR-4691") (ENT000467).

Table 8. Decontamination Cost and Effectiveness Values for Non-Farm Areas.

Based on NUREG/CR-3673 Table 4.4, and NUREG/CR-4691 (Draft July 15,1987)

Dose Rate Reduction Factor After Decontamination, (DRRF)	Mean Time to Complete Decontamination Action, (TIMDEC(days)	Approximate Costs, (USD (1984)/person)	Fraction of Cost for Decontamination Workers, (RL_f)	Worker Dose Reduction Factor (Estimated Worker Dose/Dose from Continuous Exposure), (WR_f)
3	60	2600	0.7	0.33
15	90	6900	0.5	0.33
20	120	7400	0.5	0.33

Accordingly, we believe that the DRF cases of 3 and 20 represent ±30-day sensitivity cases when compared to the 90-day base case from NUREG/CR-3673 and the early (circa 1987) MACCS code documentation. In other words, DRF=3 is the value achieved with 90-30 days = 60 days of decontamination activity, and DRF=20 is the value achieved with 90 + 30 days = 120 days of decontamination activity. The DRF = 3 case was the shorter sensitivity case and lasted 60 days. The DRF=20 case was the longer duration sensitivity case and lasted 120 days.

Q106. In your opinion, is applying a staged implementation of the decontamination and habitation plan reasonable and appropriate for the MACCS2 analysis that supports the objectives of a SAMA evaluation?

A106. (KRO, GAT) Yes. The strategy of applying a systematic and staged implementation of decontamination and habitation plan programs with different levels of decontamination effectiveness and cost strategies in a phased manner is both reasonable and appropriate in the framework of the cost-benefit analysis that underlies a SAMA evaluation. Indeed, early MACCS code documentation indicates that this staged approach to decontamination and habitation has been part of the MACCS code since its inception in the 1980s. *See* NUREG/CR-4691 (ENT000467);

Allonso and Gallego, "Cost-Effectiveness Analysis of Countermeasures Using Accident Consequence Assessment Models," *Rad. Prot. Dosimetry*, 21 (No. 1/3) pp. 151-158 (1987) (ENT000468).

By the issuance of the NUREG- 1150 study in 1990, the two retained DRF cases were 3 and 15 with DRF=15 time adjusted to 120 days (NUREG-1150, Vol. 3, Appendix D). These two DRF levels and associated times are also those applied in both Surry and Peach Bottom plants in the recently concluded SOARCA study. *See* NUREG/CR-7110, Vol. 1 (ENT000456); NUREG/CR-7110, Vol. 2 (ENT000457). In both NUREG-1150 and Draft NUREG-1935, the intermediate phase was eliminated and the long-term phase begins at seven days after plume passage over a grid element. As NUREG-1150 states:

> In the current consequence calculations, decontamination of both land and buildings was assumed to reduce the levels of radioactive material by a factor of three or 15. A reduction by a factor of three was assumed to require 60 days of decontamination work; a reduction by a factor of 15 was assumed to require 120 days of decontamination work. The decontamination efforts were assumed to commence at the end of the 7-day emergency phase. The affected people were assumed to be relocated during the decontamination period.

NUREG-1150, Vol. 3, App. D at D-30. These are the same dose reduction factor (DSRFCT) and decontamination time (TIMDEC) values used in the IPEC SAMA analysis.

Q107. In your opinion, do NUREG/CR-3673 and NUREG-1150 support the reasonableness of Entergy's use of the 60-day (DRF = 3) and 120-day (DRF = 15) decontamination time values in the MACCS2 analysis?

A107. (KRO, GAT) Yes. NUREG/CR-3673 and NUREG-1150 (including its supporting technical bases in NUREG/CR-4551) support the conclusion that the two levels of decontamination defined in the IPEC SAMA analysis are appropriate for application to model early efforts within days to weeks after plume deposition, and before weathering and both human activities (planned and inadvertent) affect the distribution of the contamination. Early actions are recognized as more effective than longer term activities, and are technically supported within the context of a probabilistic, cost-benefit analysis as noted in the aforementioned documentation.

Although other decontamination activities could take place over longer time periods (longer than a year afterward), they would constitute work performed in the long-term recovery phase where selective decontamination of specific locations may be performed (e.g., schools). The two decontamination levels applied in the IPEC SAMA analysis (DRF=3 accomplished over a 60-day period and DRF=15 accomplished over a 120-day period) are consistent with limited time availability for effective use of decontamination techniques prior to weathering and other factors we will discuss below. The two decontamination dose reduction factors and times to complete actions are consistent with NUREG-1150 as well as with present-day NRC-sponsored severe accident consequence studies.

Q108. Is there any other technical consideration that supports the use of the 60-day and 120-day decontamination times used in NUREG-1150 and the IPEC SAMA analysis?

A108. (KRO, GAT) Yes. Based on our review and evaluation, there would be at least one other technical consideration that would argue for performing decontamination activities on an expedited basis in the initial part of the long-term phase following a severe accident.

Q109. Please explain how expedited decontamination activities support the reasonableness of the decontamination times used in the IPEC MACCS2 SAMA analysis.

A109. (KRO, GAT) In general, it is recognized that expedited decontamination activities in the initial time during the long-term phase has advantages. As NUREG/CR-3673 states:

> Decontamination costs are not discounted because it is assumed that the program would be implemented as quickly as possible after accident occurrence. Although weathering and decay of radionuclides would provide incentives to delay the decontamination process, it is

> likely that migration and fixation of radionuclides onto surfaces in an area with time would make decontamination more difficult and costly. Also, delay of decontamination in an area prolongs the societal and economic disruption caused by the process. *Therefore, the most effective approach is to complete decontamination of those areas which can be restored to acceptable levels as quickly as possible.*

NUREG/CR-3673 at 4-19 (emphasis added) (ENT000466). Thus, the assumption that decontamination activities will be performed in an expedited manner is integral to the MACCS2 decontamination and interdiction model.

Based on the above discussion and an understanding of how the TIMDEC input is used in concert with other CHRONC decontamination and economic inputs, we conclude that the decontamination times utilized by IPEC for the variable TIMDEC are reasonable for the purposes of a SAMA analysis. Those same values are accepted in the PRA community and have been consistently applied in Level-3 PRA analyses (including SAMA analyses) for many years. Unlike ISR's proposed values, the IPEC TIMDEC values are not exceedingly long such that they defeat the MACCS2 internal decontamination cost/benefit optimization scheme. The values are consistent with the reasonable objective of completing decontamination activities expeditiously. The TIMDEC values represent reasonable times for the purposes of generating mean consequence results for a fifty-mile SAMA analysis region . Importantly, these variables are not intended to portray or effect the physical cessation of <u>all</u> decontamination activities following a severe accident.

3. Nonfarm Decontamination Cost

Q110. ISR identified nonfarm decontamination cost as another of the most sensitive input parameters related to decontamination costs. What is the nonfarm decontamination cost parameter, as defined in MACCS2?

A110. (KRO, GAT) The nonfarm decontamination cost (CDNFRM) input to MACCS2 defines the nonfarmland decontamination cost per individual for each level of decontamination considered (*i.e.*, DRF of 3 and 15 in the IPEC SAMA analysis). *See* Table 2, *supr*a.

Q111. What values did Entergy use for nonfarm decontamination cost?

A111. (KRO, GAT) As noted above, Entergy selected values of $5,184/person and $13,824/person for DRFs of 3 and 15, respectively. Entergy obtained these values by using the values from NUREG-1150, which were $3,000/person and $8,000/person, respectively, and then adjusting them by the CPI method in accordance with NEI 05-01. *See* A58 & A71, *supra*.

Q112. Did ISR attempt to calculate nonfarm decontamination costs for IPEC?

A112. (KRO, GAT) Yes. As described further below, ISR evaluated four alternative approaches for calculating nonfarm decontamination costs. For each approach, we evaluated the process, spreadsheets, and MACCS2 code modeling prepared or performed by ISR, as described in the ISR Report (NYS000242) and in other related documentation provided by NYS.

Q113. Please describe generally the methodology and four approaches used by ISR.

A113. (KRO, GAT) First, ISR divided the spatial grid defined in the Entergy MACCS2 site input file into two discrete areas within the 50-mile radius SAMA analysis region for purposes of evaluation. Lemay Testimony at 31 (NYS000241). ISR called these areas the "NYC metropolitan area" and "the areas outside of the NYC metropolitan area." *Id*. Second, for each of these two areas, ISR calculated the costs of light and/or heavy decontamination using the per square kilometer decontamination costs obtained from four sources:

- Approach A is based on data from the *Site Restoration Report* as modified by R.E. Luna, H.R. Yoshimura, and M.S. Soo Hoo, *Survey of Costs Arising from Potential Radionuclide Scattering Events*, WM2008 Conference (Feb. 2008) ("Luna Paper") (NYS000255);

- Approach B relies upon data from Barbara Reichmuth's presentation of results from radiological dispersal device economic consequence analysis in the U.S. (Reichmuth, et al., *Economic Consequences of a Rad/Nuc Attack: Cleanup Standards Significantly Affect Cost*, Proceedings of Working Together R&D Partnerships in Homeland Security, Boston, MA (Apr. 2005) (Pacific Northwest National Laboratory, PNNL-SA-45256) ("Reichmuth Paper") (NYS000257);

- Approach C uses information from the CONDO Report (NYS000250), which relates to a decontamination cost estimation tool from the United Kingdom's National Radiological Protection Board, and its database; and

- Approach D relies upon data from Chernobyl-related decontamination analyses completed by the Risø National Laboratory in Denmark.

Id. Third, for each approach, ISR calculated a single total cost for light and/or heavy decontamination within the 50-mile radius area. *Id*. at 32. Fourth, for each approach, ISR divided the total cost by the total population, as reported by Entergy, in the 50-mile radius area to obtain a per capita cost for light and/or heavy decontamination. *Id*. Finally, ISR updated the per capita cost for each approach to 2005 values, using the CPI. *Id*.

Q114. What were the overall results of ISR's nonfarm decontamination cost calculations under the four alternate approaches?

A114. (KRO, GAT) ISR's calculations resulted in nonfarm decontamination cost inputs significantly higher than Entergy's input values. The costs resulting from the various approaches are summarized in Table 11 (Summary of ISR's decontamination costs) of the ISR Report, which is reproduced as Table 9 below.

Table 9. **Summary of ISR's Decontamination Costs (from Table 11 of ISR Report)**

Approach	Reference or Source of Data	CDNFRM ($/person, 2005)	
		Light Decontamination	Heavy Decontamination
-	Entergy (Sample Problem A)	5,184	13,824
A	*Site Restoration*/Luna	136,000 – 272,000	449,000 – 898,000
B	Reichmuth	Not available	2000,000 – 252,000
C	CONDO	19,000 – 30,000	90,000 – 140,000
D	Risø	36,000 – 59,000	Not available
-	**Aggregate**	**19,000 – 272,000**	**90,000 – 898,000**

Q115. Does the MACCS2 source code limit the nonfarm decontamination cost input (CDNFRM) that can be calculated and considered?

A115. (KRO, GAT) Yes. The source code limits the nonfarm decontamination cost input to a maximum of $100,000/person. *See* NUREG/CR-6613, Vol. 1 at 7-11 (NYS000243).

Q116. If the MACCS2 source code limits that input to a maximum of $100,000/person, then how did Dr. Lemay and ISR generate nonfarm decontamination costs in excess of that amount using MACCS2?

A116. (KRO, GAT) By Dr. Lemay's own admission, "ISR had to modify the MACCS2 source code to allow for the greater decontamination costs calculated by the approaches I just presented and which are discussed in its report. ISR found where the authors of the code had limited the value of CDNFRM to be less than $100,000 per person and *removed this single line of code*." Lemay Test. at 50 (emphasis added) (NYS000241). As we stated earlier in connection with the TIMDEC parameter, there is no indication that the code, as modified by ISR, has been checked by someone other than the ISR code subject matter expert. Without a technical review by an independent, qualified individual, we cannot be certain that all features of the code are performing as intended.

Q117. Aside from the software configuration control concerns cited above, do you have any additional concerns about ISR's calculation of nonfarm decontamination costs under Approaches A through D?

A117. (KRO, GAT) Yes. We address the specific shortcomings of each of the four approaches in turn below.

a. ISR's Approach A: Site Restoration/Survey of Costs

Q118. Please describe ISR's Approach A - *Site Restoration/ Survey of Costs*.

A118. (KRO, GAT) ISR uses the *Site Restoration Report* (NYS000249) and the Luna Paper (NYS000255) as a basis upon which to develop alternate nonfarm decontamination cost values. ISR Report at 16-18 (NYS000242). As noted previously, the *Site Restoration Report* used historical data to estimate the costs of a cleanup following a plutonium dispersal event in an urban area, *i.e.*, Albuquerque, New Mexico.

Q119. Please describe the Luna Paper that ISR relies upon under this approach.

A119. (KRO, GAT) The Luna Paper purports to survey efforts to estimate the clean-up costs for radiological dispersion events, particularly those associated with radiological dispersion devices ("RDDs"). Luna Paper, at 1 (NYS000255). Thus, as was considered in the *Site Restoration Report*, the Luna Paper focuses on small-scale dispersion events. In fact, the Luna Paper relies heavily on information contained in the *Site Restoration Report*, which, for the reasons discussed above, does not support NYS's criticisms of the IPEC SAMA analysis. *See id.* at 2-3.

The Luna Paper includes a second set of data, *i.e.*, results from studies performed using various versions of RADTRAN, a transportation risk assessment code developed by Sandia. *See id.* at 3-5. As an initial matter, given the purpose of RADTRAN[5], the scale of any cleanup effort

[5] RADTRAN is a Sandia-developed code used for transportation risk assessment for radioactive materials. It combines user-determined demographic, routing, transportation, packaging, and materials data with

associated with these data also addresses spatially localized dose effects and releases, not on the scale of the large areas potentially affected from a nuclear facility severe accident, and thus would differ greatly from that associated with a SAMA analysis postulated severed reactor accident. Furthermore, the Luna Paper does not discuss the RADTRAN studies cited therein in any meaningful detail.

A third data set included by Luna comes from the Reichmuth Paper (NYS000257). That paper projects costs associated with three sizes of nuclear weapon detonations and a Cs-137 RDD. Reichmuth Paper at 2. Nuclear weapon detonations, however, bear little resemblance to a reactor accident due to the scale of physical damage associated with a nuclear detonation. Additionally, the Reichmuth study employs RADTRAN and also estimates costs using the *Site Restoration Report* model. *Id.* at 5-7. Therefore, the Reichmuth Paper is inapplicable to SAMA analysis for the same reasons discussed above in connection with the *Site Restoration Report* economic model

In summary, references to the Luna Paper to substantiate the magnitude of the cost estimates generated using the Sandia *Site Restoration Report* is a circular argument. Most of the data sets surveyed by Luna implicitly incorporate the Sandia *Site Restoration Report* economic model. Thus, one would expect general agreement among the data sets.

Q120. Please elaborate on the use of the Luna data and how ISR applied that data in Approach A.

A120. (KRO, GAT) To address the higher population density associated with NYC proper, Luna scaled the *Site Restoration Report* decontamination costs for residential and commercial property by a factor of 6.82 based on a ratio of the population density between Albuquerque, NM and NYC. Dr. Lemay, however, selected a different scaling approach, developing an adjustment

meteorological data, and health physics data to calculate expected radiological consequences of incident-free radioactive materials transportation and associated accident risks.

ratio of 8.98 based on residential housing density (*i.e.*, housing units/square mile). ISR Report at 16 (NYS000242). Dr. Lemay's ratio, which is based on residential housing, was applied to both residential and commercial property. *Id.*

Q121. Do you have any opinion on the appropriateness of scaling costs to account for building density?

A121. (KRO, GAT) Yes. Applying an adjustment factor based on building density may be appropriate, if the building sizes and types in the two locations are similar in nature. However, we judge the type of housing assumed in the *Site Restoration Report* and housing in New York City to be very different. The representative house in the *Site Restoration Report* has 1,600 square feet of interior space, plus a 360 square feet garage (a modest two car garage). *Site Restoration Report*, App. G at G-5 (NYS000249). One available data source (http://www.propertyshark.com/Real-Estate-Reports/2012/01/04/average-home-sizes-in-washington-d-c-atlanta-twice-as-much-as-in-new-york/) (ENT000469) indicates an average housing unit size of 1,124 square feet for New York City. Decontamination costs would be expected to be generally proportional to square footage for a residence. If a ratio of housing size also was incorporated into the assessment, then the adjustment factor would be reduced from 8.98 to 6.3 (*i.e.*, 8.98 * 1,124/1600), a reduction of approximately 30%. This does not account for the garage. Similar adjustments would be expected to be applicable to commercial property.

There is also an inconsistency in Dr. Lemay's analysis, in that Dr. Lemay included a density increase factor for the New York City region (356 km^2 per ISR Report Table 3), which accounts for less than 2% of the 50-mile radial region, but did not calculate and apply a density *decrease* factor for the other 98% of the area within the 50-mile radial region (19,986 km^2 per ISR Report Table 3). For this large area, ISR simply applied the *Site Restoration Report* values. Table 10 below develops the average housing density for the counties in the 98% of the 50-mile radial region based on the 2000 census data used by ISR for New York City, consistent with the ISR approach for the New York City area. *See* U.S. Census Bureau, New York Census Data: Population and Housing Density (ENT000471). The average housing density is 790 housing units/square mile. This would result in a housing density reduction factor of 0.507 (*i.e.*, 790/1,557). Thus, following the ISR methodology, the *Site Restoration Report* cost values should be reduced by approximately 50% for the 98% of the area outside the New York City area. This was not included in the ISR report. Given that the area outside the NYC region contributes approximately 90% of the ISR calculated value for CDNFRM (*e.g.*, \$7.85E+12/person / \$8.63E+12/person for heavy contamination from ISR Table 3), this is a significant oversight.

<u>Table 10</u>. Housing Density in 50-Mile Radial Region Exclusive of NYC

County	State	Housing Units (/mile^2)
Duchess	NY	132.4
Essex	NY	12.9
Nassau	NY	1,598.1
Orange	NY	150.4
Putnam	NY	151.5
Rockland	NY	545.1
Suffolk	NY	572.6
Sullivan	NY	46.1
Ulster	NY	68.9
Westchester	NY	807.4
Fairfield	CT	542.4
Litchfield	CT	86.2
New Haven	CT	562.6
Bergen	NJ	1,451.2
Essex	NJ	2,383.9
Hudson	NJ	5,153.8
Middlesex	NJ	883.5
Morris	NJ	371.8
Passaic	NJ	917.7
Somerset	NJ	367.7
Sussex	NJ	108.4
Union	NJ	1,868.0
Warren	NJ	115.0
Pike	PA	63.4
Average	**--**	**790.0**

Another important adjustment not included by Dr. Lemay relates to the category of "compensation." These compensation costs are included in the decontamination cost values used by Dr. Lemay. Per the *Site Restoration Report*, the compensation category addresses "compensation to private and business property owners for damage to or disposal of property, and to business firms for lost income." *Site Restoration Report*, App. F at F-7. For moderately to heavily-contaminated residential properties, these costs include replacement cost for personal property, including motor vehicles and all household furnishing and appliances. *Id.* at F-8. For heavy contamination, compensation "also includes the cost of acquisition of property." *Id.* at F-7. The *Site Restoration Report* notes that "compensation is one of the major determinants of total cost." *Id.* at F-27. For the heavy contamination case, the compensation contributes approximately 58% and 59% of the total cost for residential and commercial property. *Id.* at G-30. These compensation costs, however, are *not* applicable to the CDNFRM variable of MACCS2. These costs are captured in other MACCS2 variables, notably the variable POPCST, which addresses temporary or permanent relocation of residents and businesses in the region, including moving expenses and personal and corporate income losses for a transitional period. NUREG/CR-6613, Vol. 1 at 7-13 to 7-14 (NYS000243). To incorporate such costs into the variable CDNFRM results in double counting of costs, and also skews the internal cost-benefit decision-making subroutine within MACCS2 related to application of decontamination strategies.

To best illustrate Dr. Lemay's misapplication of the *Site Restoration Report* data, Table 11 below presents the cost categories of the *Site Restoration Report* for offsite disposal associated with heavy contamination for residential and commercial property that appear to have been applied by ISR based on Luna. (These data are prior to the application of the area fractions.) If the non-applicable cost categories are removed, the decontamination costs for residential and commercial property decrease by 60% and 59%, respectively. Incorporation of the residential square footage comparison factor would provide an additional decrease of 30%. Accounting for these two aspects together provides a reduction of approximately 72% in the cost values provided by Dr. Lemay.

<u>Table 11</u>. ***Site Restoration Report*** **Undistributed Costs for Heavy Contamination [p. G-29]**

Cost Category	Residential ($M/km^2)	Commercial ($M/km^2)	Applicability of Category to MACCS2 CDNFRM
Site Characterization	0.72	0.72	Category Applicable
Access Controls	0.25	0.25	Category Applicable
Emergency Actions	0.57	0.57	Category Applicable. Addresses application of fixatives, etc.
Compensation	175.9	499.0	***Category Not Applicable.*** Addressed by MACCS2 variable POPCST
Decontamination	15.1	47.2	Category Applicable
Disposal	103.1	297.6	Category Applicable, costs excessive due to assumptions such as all structures will be demolished, treated as radioactive waste, with no attempts at waste reduction.
Restoration	5.3	5.3	***Category Not Applicable.*** This refers to restoring grounds to park land after complete demolition.
Certification	0.3	0.3	Category Applicable
Total	301.2	851.2	

These reductions do not address the other conservative cost assumptions in the *Site Restoration Report*, such as:

- 100% of the material in the decontamination zone requires disposal as radioactive waste. *Site Restoration Report*, App. F at F-23 (NYS000249). (Removing this conservatism would likely result in a disposal cost decrease of at least 50%.)

- All structures in the heavy contamination zone would be demolished. *Site Restoration Report*, App. F at F-18 (NYS000249).

- The proposed on-site disposal system costs are noted by the authors to be a factor of two high compared to other acceptable disposal systems. *Site Restoration Report*, App. F at F-23 to F-24 (NYS000249).

In addition, potential cost savings associated with on-site disposal options were not considered by Dr. Lemay.

Q122. Do you have any other opinions on the appropriateness of ISR's reliance on the *Site Restoration Report* and the Luna Paper?

A122. (KRO, GAT) Yes. The *Site Restoration Report*, upon which the Luna Paper is based, is inappropriate for application to the IPEC SAMA analysis. The *Site Restoration Report* focuses on different events involving different radioactive materials and different accident scales than a nuclear power plant SAMA analysis. Specifically, the *Site Restoration Report* concerns cleanup of plutonium that is dispersed in a relatively small area, perhaps a few square kilometers in size. The SAMA analysis, in contrast, is focused on the cleanup of reactor fission products, potentially on a scale that is 100 times larger. The authors of the *Site Restoration Report* acknowledged as much in that report:

> In order to derive the cost estimates presented, we assumed that the size of the affected area could range from a few hundred square meters to a few square kilometers. *Our choice of the potential size of the affected area should not be used to predict the costs of accidents*. Those predictions require detailed data on the masses of material at risk, accident phenomenology, release fractions, accident location, local terrain, and meteorological conditions, *which are outside the scope of this report*. For average weather conditions and flat terrain, even for HE [high explosive] detonation, the size of the affected area might be only a very few square kilometers.

Site Restoration Report at 7-1 to 7-2 (emphasis added) (NYS000249). It appears that, because the authors of the *Site Restoration Report* did not have in view large scale accidents, little attention was given to relevant means to incorporate more cost-effective decontamination methods.

Q123. You noted that the *Site Restoration Report* focuses on different radioactive materials than does a nuclear power plant SAMA analysis. Why is that important?

A123. (KRO, GAT) As explained above, the *Site Restoration Report* is primarily concerned with the cleanup and removal of Pu-239 used in nuclear weapons, which differs in significant ways from the cleanup and removal of fission products from a nuclear power reactor severe accident. *See* A90, *supra*. Thus, while the *Site Restoration Report* estimates costs for light decontamination of residences by removing soil to a depth of 10 cm (see Table F-2), a viable alternative might involve deep plowing of the lawns and installing new turf. Such an approach would be expected to generate significantly less contaminated waste for disposal.

Importantly, because the half-life of Cs-137 (approximately 30 years) is significantly less than that of Pu-239 (24,000 years), there is some measure of dose reduction via natural decay of Cs-137 in the long term (*i.e.*, time frame of decades). This fact could dictate the specific decontamination and disposal strategies selected and allow for associated reduction in cleanup costs.

Q124. Does Dr. Lemay recognize this difference in radioactive materials in his analysis?

A124. (KRO, GAT) In part, some of the differences are recognized. However, Dr. Lemay's generalizations regarding radionuclide particle size distributions associated with plutonium dispersal events and severe reactor accidents are overly simplistic. In the ISR report, it is acknowledged that decontamination "will vary considerably in cost depending on the chosen DF and the isotope involved," but then the focus is shifted to the issue of particle size. Lemay Test. at 36:756-58. Specifically, Dr. Lemay seems to suggest that the same size particles for a given radionuclide will result no matter what type of accident condition produced them, and contrasts plutonium dispersal from a weapon-initiated release (". . . involve explosions that create large-sized aerosols") with the particle size distribution of cesium from severe reactor accidents. It is our opinion, however, that the type of release mechanism and dispersal event, and the distance of the source of the emitted radioactivity, has a strong influence on the size distribution, such that the same radionuclide can be produced in different sizes depending on the accident conditions.

For example, Baklanov and Sorenson have noted that the median particle diameter for each nuclide differs for releases from different types of nuclear process upset conditions and from different kinds of accidents. A. Baklanov and J. H. Sørensen, "Radionuclide Deposition in Atmospheric Long-Range Transport Modelling," *Phys. Chem. Earth* (8), Vol. 26, No. 01, pp.787-799, (2001) (ENT000472). For example, they note that Cs-137 aerosol particles from Chernobyl measured in European countries had an activity median aerodynamic diameter (AMAD) equal to about 1.1 micron.[6] However, the AMAD of Cs-137 from a fuel reprocessing plant release was 3 microns. They note that the aerosol size distribution may change with the height, time and, correspondingly, with distance from the release source. A table of the major radionuclides shows in the Baklanov and Sorenson paper shows that the AMAD ranges from 0.6 – 4.3 micron for radionuclides Cs-137, Cs-134, I-131, Te-132, I-133, Ba-140, Sr-89, Sr-90, Ru-103, Pu-238, and Pu-239. *Id.* at 788**.** Thus, the difference in particle size is simply not whether the contamination is plutonium or cesium but is based on the nature of release event and the distance at which contamination occurs.

Q125. Are there other factors that influence decontamination of cesium or plutonium, and the level of effort to decontaminate surfaces?

A125. (KRO, GAT) Yes. The failure to discuss other factors in the ISR report and in Dr. Lemay's testimony further underscores the overly simplistic nature of his statements regarding particle size distributions and their effect on decontamination effectiveness and costs. Other factors influence the length of time and the success level that can be achieved with decontamination in addition to the radionuclides involved in a radioactive release. A recent (2006) EPA assessment of physical and chemical decontamination technology listed these considerations:

- <u>Target Contaminants</u> - the specific radionuclide or contaminant host matrix;

6 AMAD = the diameter in the distribution for which half of the activity would be in smaller particles and half of the radioactivity would be in larger particles.

- Applicable Media and Surface Characteristics - the nature (*e.g.*, porosity or chemical characteristics) and geometry of the surface hosting the contamination;

- Waste Streams and Waste Management Issues - the primary and secondary waste-streams, quantities of waste, containment requirements, and any non-typical waste treatment, disposal, or other management issues.

- Operating Characteristics - Worker considerations (*e.g.*, any non-typical or specialized worker skills or training needed, any non-typical worker safety requirements), any necessary surface pretreatments, equipment portability or mobility, equipment weight, power requirements, installation requirements, other complementary technologies usually applied in conjunction with the subject technology; and

- Performance - information on documented performance (through treatability studies or other radiological decontamination projects); performance measures (*e.g.*, setup time, decontamination factors, removal efficiencies, depth of contamination or surface removal, number of operating personnel required, ability to clean around encumbrances, ease of technology equipment decontamination after use). EPA Technology Reference Guide for Radiologically Contaminated Surfaces, EPA-402-R-06-003, (April 2006) (ENT000475).

Thus, in summary, particle size is but one consideration in the overall consideration of decontamination effectiveness and associated costs.

Q126. Dr. Lemay opines that cesium makes decontamination activities more difficult or challenging, correct?

A126. (KRO, GAT) Yes. Dr. Lemay opines that cesium makes decontamination challenging because cesium is soluble and will migrate rapidly into porous materials such as concrete. Lemay Testimony at 37 (NYS000241). He also asserts that decontamination of cesium becomes increasingly difficult with the passage of time after a release event. *Id*.

Q127. What is your response?

A127. (KRO, GAT) We agree that both solubility and passage of time are important considerations. However, these factors support the conclusion (and assumption in the MACCS2 model) that decontamination activities should be performed as expeditiously as possible. As EPA radiological response guidance explains:

> Decontamination processes for ^{137}Cs may be thwarted by the environmental conditions that follow the event. Much of what is known about the decontamination of surfaces involves studies of dry deposition resulting from a detonation. The subsequent environmental conditions, such as wind, rain, snow, freezing rain, or high humidity, affect how the radionuclides adhere or incorporate into the material. These environmental factors affect the decontamination process. Thus, stabilization should be performed *as soon as practicable* to surfaces that are susceptible to these environmental factors, making subsequent decontamination easier. …

OSC Radiological Response Guideline, at 85 (Oct. 2006) (emphasis added). (ENT000463).

Q128. Did ISR attempt to quantify the effect of the different radionuclides expected to be released from a nuclear accident on decontamination costs?

A128. (KRO, GAT) Yes. Using the data from the *Site Restoration Report*, Dr. Lemay concluded that an appropriate "multiplicative factor" for the overall costs shown for plutonium in Table 2 of the ISR Report is necessary to estimate the costs of cesium decontamination. Lemay Test. at 37 (NYS000241). Dr. Lemay considered two cases: (1) the cost of cesium decontamination equals that of plutonium, and (2) the cost of cesium decontamination is twice that of plutonium. *Id*. at 39. He determined that the 2005-adjusted cost of light decontamination would be between \$135,927 and \$271,854 per person, while the cost of heavy decontamination would be between \$448,889 and \$897,778 per person. *Id*. at 40.

Q129. Do you agree with ISR's analysis?

A129. (KRO, GAT) No. As discussed previously, Dr. Lemay's use of the *Site Restoration Report* is not technically sound or justified. That report is not a suitable basis on which to develop decontamination cost values for severe reactor accidents involving fission products. In addition, our review of the two sensitivity studies conducted by ISR using the *Site Restoration Report*-derived inputs, as shown in ISR Report Table 3 (Suggested values of CDNFRM assuming cost (cesium) =

cost (plutonium)) and Table 4 (Suggested values of CDNFRM assuming cost (cesium) = 2 x cost (plutonium)) show that those studies are incomplete and flawed.

With respect to the sensitivity study summarized in Table 3 of the ISR Report, we previously identified two errors in Dr. Lemay's methodology related to: (1) his failure to include a density *decrease* factor for the non-NYC area (*i.e.*, 98% of the 50-mile SAMA analysis region); and (2) inclusion of "compensation" costs in the CDNFRM input parameter in MACCS2. *See* A121.

With respect to the sensitivity study summarized in Table 4 of the ISR Report, the same two significant errors are present. However, in this case, they are scaled upwards by a factor of two, apparently on the basis of two other studies relied upon by Dr. Lemay.

Q130. Which studies did ISR rely upon in performing the second sensitivity analysis (see ISR Report, Table 4: Suggested values of CDNFRM assuming cost (cesium) = 2 x cost (plutonium)) mentioned above?

A130. (KRO, GAT) First, ISR evaluated the results obtained from the "Holt" study described in Exhibit NYS000259. *See* Letter from K. Holt, Sandia National Laboratories to M. O'Neill, Cellular Engineering, with encl. "Testing for Radiological Decontamination Strippable Coating for Cellular Bioengineering, Inc. (Cs-137, Pu-239, Am-241)" (Oct. 7, 2007) ("Holt"). In that experiment, Sandia attempted to remove both cesium and plutonium from concrete using a decontamination technique called "strippable coatings." Sandia's results show that using this technique, it could achieve a DF of 1.2 for cesium and a DF of 5.8 for plutonium, ostensibly suggesting that cesium was about five times more difficult to remove than plutonium.

Q131. Please elaborate on the strippable coatings technique and your observations regarding the Holt study.

A131. (KRO, GAT) The Holt study involved a test series in which a single type of strippable coating (Decon Gel 1101) was utilized on "test coupons" made from four different materials, *i.e.*, concrete, carbon steel, stainless steel, and plexiglas. Holt at 1 (NYS000259). Sandia applied Cs-137, Am-241, and Pu-239 to the various test coupons in solution form, allowed the applied contamination to dry, and recorded baseline activity measurements. *Id.* at 2. It then applied the strippable coating to the test coupon, allowed it to dry for 24 hours, and removed the strippable coating. *Id.* Activity measurements were repeated, and percent decontamination factors were calculated. *Id.* at 3-4. Table 12 provides the results for the Cs-137 and Pu-239 test coupons of all the material types, along with a calculated decontamination factor.

Table 12. **SNL Decon Gel 1101 Test Results**

Coupon Material	Contaminant	Sample #	% Decon	DF
Concrete	Cs-137	1	17.07	1.2
		2	15.55	1.2
	Pu-239	5	82.49	5.7
		6	71.46	3.5
Carbon Steel	Cs-137	7	99.02	102
		8	98.62	72
	Pu-239	11	99.09	110
		12	97.88	47
Stainless Steel	Cs-137	13	96.11	26
		14	98.06	52
	Pu-239	17	82.64	5.8
		18	94.31	18
Plexiglas	Cs-137	19	99.44	179
		20	99.62	263
	Pu-239	23	53.09	2.1
		24	55.17	2.2

From these test data Dr. Lemay concludes that "cesium is about five times more difficult to remove than plutonium." Lemay Test. at 38 (NYS000241). That conclusion is incorrect and appears to be drawn from a single coupon test comparison for concrete (*i.e.*, Cs-137 DF = 1.2 versus Pu-239 DF=5.7). In fact, Dr. Lemay's conclusion is based on both a major over-simplification and mischaracterization of the data. Using Dr. Lemay's selective approach, one could just as easily say (albeit incorrectly) that the above test data show that removing cesium is approximately *100 times easier* than plutonium (if drawn only from the results for Plexiglas). In short, broadly extrapolating these strippable coating test data as Dr. Lemay does in his testimony is not technically justified.

Although we do not purport to make similarly overbroad extrapolations, we note that the Holt study data do show that very high decontamination factors were achieved. The minimum decontamination factor achieved for materials other than concrete was a DF of 26, a factor that is appreciably higher than the DRF of 15 used in the IPEC SAMA analysis. It also is noted that the very high factors achieved for Plexiglas may very well also be obtained for normal glass, a material that is prevalent in urban structures. Additionally it is noted that other decontamination approaches would support significant DFs for concrete. *See* EPA, Technology Evaluation Report 600/R-11/083, Environmental Alternatives, Inc. Rad-Release I and II for Radiological Decontamination (June 2011) (ENT000473); EPA, Technology Evaluation Report 600/R-11/014, Empire Abrasive Blast N'Vac for Radiological Decontamination (May 2011) (ENT000474).

Q132. Please describe the second study that Dr. Lemay relied upon in performing the sensitivity analysis summarized in Table 4 of the ISR report.

A132. (KRO, GAT) Dr. Lemay also applied portions of several datasets from the CONDO software tool. The referenced CONDO dataset is Table A7, "Decontamination factors" from T. Charnock, J. Brown, A.L. Jones, W. Oatway and M. Morrey, *CONDO: Software for Estimating the Consequences of Decontamination Options, Report for CONDO Version 2.1. (with Associated Database Version 2.1)*, National Radiological Protection Board, Chilton, Didcot, UK (May 2003) (NYS000250). The table lists a series of decontamination techniques, the type of surface being decontaminated, the time over which the DF is applicable, and the DFs. The DFs are provided for "cesium" to represent the cesium and ruthenium element classes (*i.e.*, for beta/gamma emitters), and for "plutonium" to represent the plutonium element class (*i.e.*, all alpha emitters).

The database is not sufficiently complete to conclude, as Dr. Lemay does, that "the DFs for cesium is always less or equal to the DFs for plutonium in the CONDO dataset." LeMay Test. at

38:809-811. In fact, of the 61 decontamination technique/surface pairings listed in the CONDO Report, only the seven high-pressure hosing results for buildings (roofs and walls) can be clearly differentiated as resulting in a higher DF (10-dry deposition; 2-wet deposition) for plutonium than for cesium (DF = 2, but the deposition type is not specified). The reader is left to speculate as to whether the same DFs would have been achieved had both wet and dry deposition also been evaluated for cesium in those cases. Fifty-two of the remaining 54 sets of results are *numerically identical*. In two cases involving fire hosing of building roofs, the DF reported for cesium (1.4) was marginally better than that reported for plutonium (1.3). *See* Table A7 (Decontamination) of the CONDO Report at 47 (NYS000250).

In short, the "current data" selectively identified by Dr. Lemay from the CONDO Report are too limited and insufficient to support his conclusion that the DF for cesium may be less than or equal to plutonium, but will never be greater. Furthermore, the dataset in question is based on two reports by the same lead author (J. Brown). In our view, the DF estimates do not appear to be representative of a broad range of decontamination field studies encompassing sufficient decontamination experience to draw any statistically-based conclusions.

Q133. Based on your review of the Holt and CONDO Report datasets, please summarize your opinion on the appropriateness of Dr. Lemay's reliance on them.

A133. (KRO, GAT) Based on our review of the two datasets, the "current data" cited by Dr. Lemay do not provide a sufficient basis for his assumption that "the cost of cesium decontamination is twice that of plutonium." (NYS000242, page 17) In fact, the Holt study data presented in Table 12 above contradict Dr. Lemay's assumption. Thus, there is no valid technical basis for his decision to multiply the CDNFRM input value used in MACCS2 by a factor of two. Given the significant flaws already identified in A121 above (*i.e.*, the lack of adjustment to the cost for the area outside of New York City and the incorrect set of costs attributed to CDNFRM), Dr. Lemay's suggested CDNFRM values in Table 3 and Table 4 in the ISR report, which are based on cost data from the *Site Restoration Report* and Luna Paper, are in error and without technical merit.

Q134. Returning to Dr. Lemay's reliance on the *Site Restoration Report*, you mentioned earlier that the report focuses on different accident scales than those considered in a SAMA analysis for a nuclear power plant. Please explain why that is significant.

A134. (KRO, GAT) As we explained above, the *Site Restoration Report* focuses on the decontamination of a relatively small area due to the nature of the event being evaluated (*e.g.*, aircraft crash). This is evidenced by the historical case studies identified in Appendix A of the report. For instance, the Thule Greenland clean-up effort was limited to 0.06 km^2 (with a final decontamination factor of 14) [page A-2]. The Enewetak Atoll clean-up effort involved 0.33 km^2. The Johnston Island clean-up effort reportedly involved an ongoing radiological control area (RCA) of 0.109 km^2 and a decontamination effort for 0.097 km^2 of the RCA. In comparison, the cleanup region for a severe accident addressed in the SAMA analysis could involve a land area that is two orders-of-magnitude greater than envisioned in the *Site Restoration Report*. As noted previously, the cleanup required for a SAMA analysis event would be expected to benefit from "economy of scale" attributes that do not appear to have been examined in the *Site Restoration Report*.

Q135. Can you provide some examples to illustrate this point?

A135. (KRO, GAT) Yes. For instance, the cost estimates proposed in Table 6-2 of the *Site Restoration Report* are based on disposal at an "off-site" facility. *Site Restoration* Report at 6-5 (NYS000249). Section F.7 of the report notes that there are conservatisms in those disposal estimates. First, the study notes that these values are conservative with respect to the amount of material requiring disposal. The report states:

> The present [disposal] estimates are based on the assumption that *all material removed, whatever its contamination level, would be disposed of as radioactive waste*. The reason for this assumption, which may be conservative, is that we were not able to estimate what fraction might be free of contamination. It is also possible that the cost of monitoring or segregating waste would cost as much as disposing of all waste as if it were contaminated. Waste disposal is a major cost element, and our conservative assumption is a possibly important source of uncertainty.

Id. at F-23. In our opinion, the scale of a clean-up following a nuclear power plant severe accident, as postulated in a SAMA analysis, could not practically employ the assumption that "all material removed" requires disposal as contaminated material.

Additionally, *Site Restoration Report* states that the authors did not consider the potential for waste volume reduction "because there would be little cost savings for waste containing building rubble, which would probably have to be ground up, and because of the modest volume reduction achievable with current technology." *Id.* at F-25. Yet the report acknowledges that "a 50-60% volume reduction is possible for most soils" and "commercially available technology may be worth considering for farmland or rangeland decontamination, because waste disposal is a major cost element." *Id.* We would expect approaches for waste volume reduction to be pursued for a large-scale clean-up effort such as that associated with a nuclear power plant severe accident.

The *Site Restoration Report* also develops cost estimates for disposal at an "on-site" facility. *Id.* at F-23 to F-24. These "on-site" costs are significantly less than those used in the ISR Report. For instance, in the *Site Restoration Report*, the decontamination costs for residential property using on-site disposal are lower by 36% (light contamination), 20% (moderate contamination), and 18% (heavy contamination). The *Site Restoration Report* further notes that there is considerable conservatism in this on-site disposal cost estimate due to its focus on plutonium contamination:

> For on-site disposal we postulated many precautions taken to minimize the possibility of intrusion or leakage, based on the public's aversion to plutonium. We designed a disposal site incorporating those precautions.

> The cost would be higher than some other estimates…. The unit cost would be approximately double the median cost of current estimates… In our judgement [sic], *on-site disposal costs would be only about one-half of our estimates in a well-sited land burial facility* complying with the minimum requirements of 10 CFR 61.

Id. at F-23 to F-24 (emphasis added). Thus, the on-site disposal costs proposed in the main portion of the report are at least a factor of two high compared to other acceptable options. This factor of two may be acceptable for clean-up of a small-scale incident but, in our view, is unacceptable for estimating the clean-up cost of a large-scale event such as nuclear power plant severe accident.

In summary, the clean-up of large-scale contamination from a nuclear power plant severe accident would differ in fundamental respects from the clean-up of a small-scale plutonium dispersal event. The combination of the few factors identified above (*i.e.*, separating non-contaminated materials from contaminated materials, employing waste volume reduction, on-site interim storage) alone could readily reduce the decontamination cost by a factor of two or three relative to cost incorporated by Dr. Lemay in his analysis. As the *Site Restoration Report* states: "Readers are thus urged to critically evaluate the applicability of our estimates to the application at hand." *Id*. at 6-1.

b. <u>ISR's *Approach B: Reichmuth*</u>

Q136. Please describe Dr. Lemay's use of Reichmuth's studies under Approach B of the ISR Report.

A136. (KRO, GAT) Dr. Lemay's second approach (Approach B) also is based on a purported comparison of economic costs associated with nuclear weapon and RDD detonations, as reported in a short paper (NYS000257) by Barbara Reichmuth (lead author) for New York City and a few other US cities, and a brief reference to a second report by Reichmuth regarding a study involving the city of Vancouver. We refer to NYS000257 below as the Reichmuth Paper.

The Reichmuth Paper projects economic consequences associated with three nuclear weapon detonations of varying sizes and a Cs-137 RDD in the New York City area. Reichmuth Paper at 2. Its focus is "primarily on the economic consequences of a nuclear weapon attack; the impacts of an RDD are still under investigation and will merit further research." *Id.* at 3. Reichmuth developed economic cost estimates based on two sources: "the economic model provided as a companion to the RADTRAN 5 computer code" (*id.* at 5) and a Federal Reserve Bank of New York ("FRBNY") study of the economic effects of the 9/11 terrorist attack on the World Trade Center ("WTC") in New York City. *Id.* at 5-7.

The first source, the economic companion model to RADTRAN 5, is again based on the *Site Restoration Report* methodology. The Reichmuth Paper explicitly references the *Site Restoration Report* and states that "[t]his economic model was initially developed to estimate the economic consequences of plutonium-dispersal accidents." *Id.* at 5. We already explained the many reasons why the *Site Restoration Report* is inapplicable to a SAMA analysis. *See* A122-123, A134-135.

Because of the difference in the population of the area (Albuquerque, NM) considered in the *Site Restoration Report* versus New York City, Reichmuth did not use RADTRAN 5 as a basis for estimating the economic impacts to New York City. Instead, Reichmuth based those estimates on cost information from the FRBNY WTC-related study. Significantly, the Reichmuth Paper states:

> [T]he WTC site is not representative of New York City in general or any other major population center in the United States because of the unique and very high value buildings that stood on this site and which will be replaced with equally high value buildings. The replacement value reported in the FRBNY study is therefore likely to be much higher than would be expected for the average high density urban area. Taking this important point into consideration, the FRBNY data were used to derive the unit cleanup costs for high and very high density urban areas reported in Table 1.

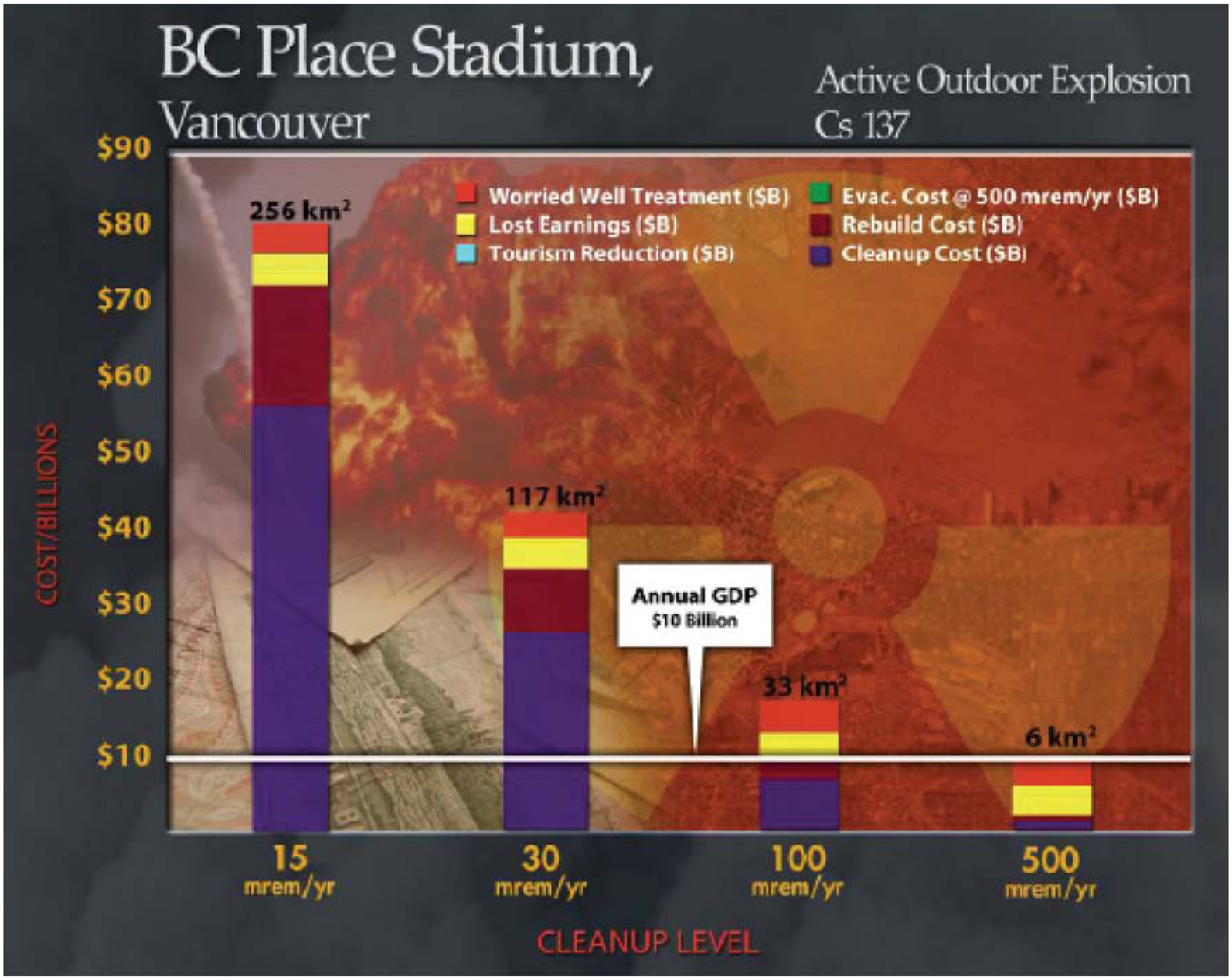
Id. at 7. The details of this derivation, including Reichmuth's scaling of the FRBNY cost data, however, are not available for review to determine their appropriateness.

The unavailability of these details is significant because the WTC event involved no radiological materials. There is simply no basis presented for how Reichmuth used a non-radiological event involving enormous structural damage (the 9/11 WTC attacks) to estimate cleanup for a radiological event (*i.e.*, RDD), in which the structural damage is essentially non-existent. It appears that Reichmuth assumed that all contaminated structures would require demolition. Similarly, Dr. Lemay's application of the Reichmuth numbers is not explained in, or otherwise clear from, his testimony or the ISR Report. He calculates a decontamination cost per person of \$200,000 based on an affected area of 10 km^2 and a restoration cost of \$20 billion, for a cleanup standard of 500 mrem/year. ISR Report at 19 (NYS000242). But neither the 10 km^2 area nor the \$20 billion cost figure appears in the Reichmuth Paper discussion of a Cs-137 RDD event in New York City. It appears that Dr. Lemay may have estimated the \$20 billion figure from Figure 9 of the Reichmuth Paper (NYS000257), but that figure (putting aside its lack of demonstrated relevance here) does not have sufficient fidelity to support such an estimate.

Q137. Please describe the second Reichmuth paper on which Dr. Lemay relies on under Approach B in the ISR Report.

A137. (KRO, GAT) The second Reichmuth paper relied upon by Dr. Lemay does not appear to be publicly available and was not provided by NYS as an exhibit. The citation for this paper is Tom Cousins and Barbara Reichmuth, *Preliminary Analysis of the Economic Impact of Selected RDD Events in Canada*, Defence Research and Development Canada and Battelle, PNWD-SA-7845 (2007). The paper is only briefly mentioned in Exh. NYS000262, CRS Report R41890, *"Dirty Bombs": Technical Background, Attack Prevention and Response, Issues for Congress*, Congressional Research Service (Jun. 24, 2011) ("CRS Report"). The CRS Report briefly describes this additional paper by Reichmuth, noting that it considers the economic impacts of a postulated explosive-driven RDD containing 1,000 curies of cesium-137 that is detonated at BC Place Stadium in Vancouver, British Columbia. CRS Report at 15 (NYS000262). It also includes two figures from Reichmuth's paper. *See id.* at 16-17 (Figs. 2 & 3).

According to the CRS Report, Reichmuth estimated costs of $10 billion (Canadian dollars) for a release resulting in a dose of 500 mrem per year over an area of 6 square kilometers (km^2). *Id.* at 16. This estimated cost is visually depicted in Figure 3 (Area Contaminated to Various Levels, and Resulting Costs) of the CRS Report. *Id.* at 17. Figure 3 of the CRS Report is reproduced as Figure 6 below. It appears that Dr. Lemay converted the costs from Canadian dollars to U.S. dollars to arrive at the value of $8 billion reported in Table 5 of the ISR Report. However, Dr. Lemay failed to recognize that the cost category denoted "Cleanup Cost" constitutes only a small fraction of the $8 billion total. From the figure above, cleanup costs are visually estimated to be about $1.5 billion, or only 15% of the total $10 billion cost. Thus, in U.S. dollars, the estimated cleanup cost would be $1.2 billion. This would adjust Dr. LeMay's calculated cost per person value from $251,493 to $37,724 (*i.e.*, an 85% reduction). It bears emphasis that the CRS Report provides *no* details regarding the cleanup cost estimate reported in the second Reichmuth paper (which, as noted above, does not appear to be publicly available). If this cleanup cost estimate is based on the *Site Restoration Report* estimates, then all of the associated (and large) conservatisms in those estimates, as discussed above, would equally apply.



<u>Figure 6</u>. Area Contaminated to Various Levels, and Resulting Costs For an Attack Using 1,000 Curies of Cesium-137 (from CRS Report at (NYS000262))

Q138. What did Dr. Lemay conclude based on the two Reichmuth papers you just described?

A138. (KRO, GAT) Dr. Lemay concluded that the decontamination techniques proposed by Reichmuth correspond to "heavy decontamination." ISR Report at 19 (NYS000242). Therefore, using Reichmuth's results, the cost for nonfarm heavy decontamination equivalent to Entergy's DRF of 15 would be between $200,000 and $252,000 per person, according to Dr. Lemay.

Q139. Do you have an opinion on the propriety of ISR's reliance on information from the two Reichmuth papers?

A139. (KRO, GAT) Yes. Neither of the Reichmuth papers (the second of which was not provided to the parties or the Board) provides sufficient information to allow a reasonable and reliable comparison to the costs of a nuclear power plant severe accident. The first paper is concerned principally with postulated nuclear weapon attacks, and presents only a "preliminary assessment of the economic consequences of a 10 kilocuries (or 10,000 curies) of Cs-137 RDD in New York City" based on cost information associated with a *non-radiological* event (*i.e.*, the WTC attack). Nuclear weapon detonations bear little resemblance to a reactor accident due to the extent of physical damage associated with a nuclear detonation. Therefore, estimates of economic consequences of a nuclear weapon detonation in New York City are not relevant to a SAMA analysis. As explained above, the data from the second Reichmuth paper were obtained indirectly from the CRS Report (NYS000262), were misapplied by Dr. Lemay, and should be discounted by at least by 85%. The technical basis for the remaining 15% is unknown.

In our professional opinions, Dr. Lemay's reliance on the information from the cited Reichmuth papers is misplaced and lacking technical justification. The cost information obtained from those papers is not a reliable proxy or benchmark for the decontamination cost and other economic inputs used in the MACCS2 portion of the IPEC SAMA analysis.

c. ISR's Approach C: CONDO Report Cost Data

Q140. Please briefly describe CONDO and Dr. Lemay's use of CONDO-related data in Approach C.

A140. (KRO, GAT) CONDO is a software tool for estimating the consequences of decontamination options developed by the National Radiological Protection Board (NRPB) in the United Kingdom. The cited report in NYS000241 describes the 2003 release of Version 2.1 of CONDO (NYS000250).

In describing ISR Approach C, Dr. Lemay states that he performed calculations in CONDO to obtain a range of decontamination values for light decontamination, Entergy's DRF of 3, and heavy decontamination, Entergy's DRF of 15. Lemay Test. at 43-44 (NYS000241).

For the first CONDO calculation, ISR assumed that the NYC metropolitan area has an urban population density of greater than 1,000 persons per km^2, and that all other areas have a population density less than 1,000 persons per km^2. *Id.* ISR performed this "calculation" for light and heavy decontamination. *Id.* For its second CONDO calculation, ISR assumed that the NYC metropolitan area has a hyper-urban population density of about 10,000 persons per km^2, and that all other areas have a population density between 1,000 and 10,000 persons per km^2. *Id.* ISR performed this "calculation" for light and heavy decontamination. *Id.*

However, upon examination of the ISR report, it appears that ISR obtained decontamination cost and other related data from the CONDO Report (NYS000250) and entered those data into user-developed spreadsheets, but did *not* actually apply the CONDO software, as might be wrongly inferred from Dr. Lemay's statement that "ISR performed calculations in CONDO to obtain a range of decontamination values." *Id.* Thus, based on our review of available information, Approach C may be more accurately described as manually adjusting data extracted from tables in the CONDO Report and then performing user-developed spreadsheet calculations.

Q141. What were the results of ISR's CONDO-related calculations in Approach C?

A141. (KRO, GAT) First of all, ISR results are provided in terms of light decontamination activities (decontamination factor =3) and heavy decontamination activities (decontamination factor = 15) applied in the fifty-mile IPEC SAMA region. In the ISR study, the New York City (NYC) metropolitan area is characterized as either urban or hyper-urban by population density, and the area outside the NYC metropolitan area but still in the 50-mile SAMA region as either semi-urban or urban. After weighting the costs per unit area of these two regions by the areas covered, two pairs of results were reported. ISR concluded that the cost of light decontamination activities should be between \$19,431 and \$29,933 per person, while the cost of heavy decontamination would be between \$89,734 and \$140,430 per person. LeMay Test. at 44; ISR Report at 21.

Q142. Did you identify any errors in ISR's application of the CONDO data?

A142. (KRO, GAT) Yes. We identified numerous errors or application discrepancies in ISR's use of the CONDO data, as described in Approach C of the ISR Report. These errors and discrepancies are described below.

Q143. Although the ISR Approach C used data from the CONDO report and applied those data in ISR-developed spreadsheets rather than running the CONDO code itself, why would that approach lead to results different from running the code?

A143. (KRO, GAT) Executing, or running the CONDO code successfully requires that the user comply with the inputs and model calculations as specified in the code documentation and removes user subjectivity and biases. In contrast, a user-developed spreadsheet based on the CONDO database may have user-based errors, make incorrect use of data, or reflect user biases.

For example, in the ISR Report, of the 61 techniques listed in the CONDO report, seven are picked by ISR without any apparent justification or basis. Seven decontamination techniques–surface pairs are listed for light decontamination (achieving a decontamination factor (DF) = 3) and seven decontamination techniques–surface pairs are listed for heavy decontamination (DF=15). However, closer inspection reveals that the specific techniques are not consistent with the chosen level of decontamination. For light decontamination (defined by ISR as DF=3), the DFs for the techniques range from 1.4 to 10. For heavy decontamination (defined by ISR as DF = 15 in MACCS2), the techniques range from 1.4 to 50 with the same technique, "vacuum, cleaning, and washing" listed in both with the same decontamination factor.

Q144. Are all techniques applied objectively in the various decontamination activities that are applied in the ISR Approach C?

A144. (KRO, GAT) No. Despite the availability of 61 decontamination techniques to apply from the CONDO database, ISR Approach C appears to weight its results predominantly on decontamination of internal walls in buildings and relies on one decontamination technique in all of its spreadsheet calculations. That is, one technique, that of vacuuming, cleaning and washing, is a dominant contributor for the semi-urban, urban and hyper-urban population densities areas described in the ISR Report. With an internal wall weighting factor developed in the ISR spreadsheets, this single decontamination technique controls the outcome of the individual spreadsheets for the Approach C analyses. This is not reasonable because building interiors should be less contaminated than the building exteriors.

Thus, ISR appears to have chosen techniques without a basis (A143) and outside the context of the CONDO software application, and then relied on one technique to arrive at its estimated decontamination costs. (See Tables 20 and 21 in NYS000242). Whether the same results would be obtained in the CONDO code itself is unknown, because Approach C relies on ISR-generated spreadsheets that are given without a technical basis and essentially relies on one decontamination approach. One thing is clear: ISR's approach is not objective and unreasonably skews the analysis results in favor of higher estimated decontamination costs.

Q145. One of the two sensitivity cases presented in the ISR report (Table 8; NYS000242, page 21) considers the NYC metropolitan area as a hyper-urban density population area and everywhere else in the 50-mile SAMA analysis region to be an urban density area. Is this case a valid sensitivity case?

A145. (KRO, GAT) No. The results are invalid for several reasons. First, the hyper-urban case is not based on the CONDO report. Rather, it a construct created and defined by ISR (NYS000242). The ISR report develops a hyper-urban category of environment to account for a population density of greater than 10,000 persons/km^2 for the New York City region. This category is not supported by the CONDO report land use and housing indices which apply rural (<25 persons/km^2), semi-urban (>25 but $\leq$ 1,000 persons/km^2), and urban (> 1,000 persons/km^2) designations. Second, the 50-mile (80-km) SAMA analysis polar grid indicates that only one of eighty 22.5-degree sector elements (1.8% of the total SAMA grid area) meets the ISR definition of hyper-urban (10,000 persons per km^2), and that 68 of the remaining grid elements (81.5% of the total SAMA grid area) would not meet the definition of an urban area. Specifically, the CONDO documentation indicates that a population density of 1,000 persons/km^2 is required to be classified as an urban population density area.

Thus, the hyper-urban density case (Table 8 in the ISR report) has no basis because it does not meet the ISR-defined population density criteria in most of the SAMA analysis region, and is not a CONDO-recognized use of the data. It is our judgment that ISR's hyper-urban density case is a flawed and invalid sensitivity analysis.

d. __ISR's Approach D: Risø Report Cost Data__

Q146. Please describe how Dr. Lemay calculated decontamination costs under Approach D in the ISR Report.

A146. (KRO, GAT) Under Approach D, ISR repeated the methodology used for the CONDO approach, but substituted the costs per km^2 reported by Denmark's Risø National Laboratory in the 1995 Risø Report (NYS000251) for the costs reported in the CONDO dataset. Risø independently assessed decontamination costs for a variety of decontamination techniques on a variety of surfaces (pavement, grass, etc.). Lemay Test. at 46 (NYS000241). For this approach, Dr. Lemay chose decontamination techniques from the Risø Report that most closely correlated to those selected in the CONDO analysis. *Id.* For each type of area (hyper-urban, urban, semi-urban), the fraction of land covered by a given type of surface was taken from CONDO, and the cost per km^2 was calculated using the Risø values. *Id.* The rest of the cost evaluation used the same methodology as the CONDO analysis described above. *Id.* Because all of the Risø techniques are recommended only for light decontamination, Dr. Lemay did not use Risø to calculate CDNFRM for heavy decontamination. *Id.*

Q147. Is the Risø Report based on a particular event?

A147. (KRO, GAT) Yes. The Risø Report, which was issued in 1995, states that "the estimates were based on experimental work to assess the effect of dose reducing countermeasures in areas contaminated about 9 years ago by radioactive matter released during the Chernobyl accident." Risø Report at 5 (NYS000251).

Q148. What were the results of Dr. Lemay's analysis using the Risø Report?

A148. (KRO, GAT) Using Risø data, ISR determined that the cost of light decontamination would be between $36,000 and $59,000 per person. Lemay Test. at 47 (NYS000241); ISR Report at 22 (NYS000242).

Q149. Did you review Dr. Lemay's analysis under Approach D?

A149. (KRO, GAT) Yes, but we could perform only a partial review due to the lack of complete information in the ISR Report and NYS's associated exhibits. The ISR Report is not clear with respect to the decontamination processes selected and surfaces being decontaminated. It simply indicates Dr. Lemay's purported use of Risø data and maintains the area-specific values derived from the CONDO study (hence, the numerous flaws in Dr. Lemay's Approach C, as identified above, also apply to Approach D). However, instead of using seven decontamination technique/surface pairs (as in Approach C), Approach D uses only five such pairs. ISR Report at 54-56 (Tbls. 26-28) (NYS00242). Dr. Lemay provides no explanation or technical basis for his selection of the five decontamination techniques/surface pairs in the ISR Report or in his testimony. Notably, he claims that Approach D is limited to light decontamination costs on the basis of the Risø Report. Lemay Test. at 46 (NYS000241). However, the Risø Report lists a DF greater than 100 for the vacuum cleaning and changing of wall paper process, and a DF = 28 for the cutting or removal of the soil layer. Risø Report at 24, 32 (NYS000251). These DFs correspond to heavy decontamination, as defined in the ISR Report. This is not the only inconsistency or uncertainty associated with ISR Approach D.

Q150. Do you have an opinion on Dr. Lemay's conclusion that the cost of light decontamination would be between $36,000 and $59,000 per person under Approach D?

A150. (KRO, GAT) Yes. Based on the limited information available to us, we could not duplicate, much less verify, Dr. Lemay's derivation of the Approach D decontamination cost figures. For example, the Risø Report does not report decontamination-related costs in Euros or U.S. dollars (USD), but instead expresses cost data in terms of level of effort, overheads, and tool investment cost (as 1995 European Currency Unit, or ECU) for special equipment, etc. *See*, *e.g.*, Risø Report at 11 (NYS000251). It is not evident how Dr. Lemay converted those units to U.S. dollars. He presents no assumptions on specific labor rates in his testimony or report. Apart from ISR's simple scaling of ECU to USD in 1995, and his CPI-based adjustment from 1995 to 2011 USD, the quantitative bases for his Risø-derived cost estimates are unknown. Consequently, we could confirm neither the validity of Dr. Lemay's interpretation of the cost data in the Risø Report, nor the accuracy of the starting and final costs listed in Tables 26-28 of the ISR Report. Accordingly, those cost figures cannot be deemed reliable as a technical matter.

Q151. Please summarize the conclusions reached from your overall review of Dr. Lemay's decontamination cost calculations in Approaches A through D of the ISR Report.

A151. (KRO, GAR) In our opinion, Dr. Lemay has failed entirely to justify his proposed nonfarm decontamination cost (CDNFRM) values. In short, in developing his proposed values, he has misread, mischaracterized, and misapplied data on which he relies. Furthermore, as we explained above, the sources and data on which he relies are largely inapplicable to a SAMA analysis for U.S. nuclear power plant (in this case, Indian Point Units 2 and 3).

4. Value of Nonfarm Wealth

Q152. ISR identified the per capita value of nonfarm wealth (VALWNF) as another sensitive MACCS2 input parameter related to decontamination costs. What did it conclude with respect to Entergy's VALWNF value?

A152. (GAT, LAP, KRO) ISR concluded that Entergy's calculations of nonfarm wealth were "outdated since the values obtained from SECPOP2000 were not scaled up from 1997 values to 2004 values." Lemay Test. at 58.

Q153. Is ISR correct that Entergy did not scale up the 1997 SECPOP2000 values to 2004 values?

A153. (GAT, LAP, KRO) Yes. However, scaling up to 2004 values would have no impact on the IPEC SAMA analysis. As discussed previously, the original VALWNF value was based on data contained in the SECPOP2000 computer program, specifically, the economic database for 1997. This was included in the original SAMA base case analysis to develop a value of $163,631/person for the 50-mile region. Entergy later increased the value of VALWNF to $208,838/person (a factor of 1.28 increase) as a result of the NRC Staff's request that it include the sensitivity case for lost tourism and business in the base case analysis.

If the VALWNF value of $163,631/person was escalated from 1997 to 2005 using the CPI as suggested in NEI 05-01, the increase factor would be 1.22 (*i.e.*, CPI value of 195.3 for 2005/CPI value of 160.5 for 1997). Thus, the increase factor associated with lost tourism and business applied by Entergy in its updated SAMA base case bounds that associated with escalating the VALWNF value from 1997 to 2005. We also note that simply adding the postulated economic impact associated with lost tourism and business based on a gross county product to the SECPOP2000 value based on reproducible tangible wealth, as performed by Entergy, likely involves some double counting of economic impacts, resulting in additional conservatism in the VALWNF value applied by Entergy in its SAMA analysis.

In view of the foregoing, we conclude that the VALWNF value used in the IPEC SAMA analysis is reasonable and appropriate for such an analysis.

5. Per Capita Cost of Long-Term Relocation

Q154. ISR also identified per capita cost of long-term relocation (POPCST) as another sensitive MACCS2 input parameter related to decontamination costs. Please describe what this input measures.

A154. (GAT, KRO) As noted above, POPCST represents the per capita removal cost for temporary or permanent relocation of population and businesses in a region rendered uninhabitable during the long-term phase.

Q155. What per capita cost of long-term relocation values did Entergy use in its analysis?

A155. (GAT, KRO) POPCST was developed in NUREG/CR-4551 with a value of $5,000/person on the basis of per capita lost wages ($14,600/person-year, national value) for 140 days (*i.e.*, 20 weeks). NUREG/CR-4551, Vol. 2, Rev. 1, Pt. 7 at 5-3 (NYS000248). Entergy escalated the POPCST value using the CPI to a value of $8,640/person. The Entergy value is reflective of per capita lost income of $61.70/person-day. It is noted that for the SAMA analysis, this value applies to each individual relocated whether they are an adult or child, employed or unemployed. Thus, for a household of three, the POPCST would provide $25,920, reflecting a per-household lost income of $185.10/day.

Q156. What was ISR's assessment of Entergy's selection of this value?

A156. (GAT, KRO) Although ISR agreed with Entergy that the moving expenses would contribute very little to the cost of long-term relocation (because the majority of the personal belongings would be contaminated), "ISR felt that given current unemployment benefits policies in the State of New York, it seemed that 140 days of lost wages was too low." Lemay Test. at 60 (NYS000241). Dr. Lemay noted that New York State unemployment benefits normally last 26 weeks (182 days) and have recently been extended to 93 weeks (651 days). *Id*. Based on those assumptions, ISR calculated the cost of long-term relocation by multiplying the 2005 average income per capita ($76/day) by a range of duration for the lost wages. The resulting costs were $10,640/person (for 140 days of lost wages) to $49,857/person (for 93 weeks of lost wages). *Id*.

Q157. Do you have an opinion on ISR's assessment and assumptions used?

A157. (GAT, KRO) Yes. Use of a New York State value rather than national value is reasonable. The ISR daily rate is approximately 23% higher than the value used by Entergy. However, with regard to the length of time that the workers are assumed out of work, we disagree that the term of unemployment benefits in New York State is an appropriate basis for comparison. Historical unemployment durations, in our view, provide a more reasonable basis.

According to the Bureau of Labor Statistics ("BLS"), the median and average duration of unemployment in the U.S. in 2005 (the reference year for the SAMA economic inputs) was 8.9 weeks and 18.4 weeks, respectively. *See* Grant Teagarden, Unemployment Duration Calculation (Feb. 2012) (ENT000476). Although these 2005 values may be lower than current values associated with the recession, these 2005 values are still higher than broader historical unemployment durations. Based on BLS data from 1970 through 2010, the average unemployment duration over this 41-year time period is 15.5 weeks, with the average median duration being 7.9 weeks (approximately 55 days). *Id.*

Based on this BLS data, the assumption utilized in the SAMA analysis of 20 weeks (*i.e.*, 140 days), is reasonable and, in fact, somewhat conservative. Based on the 41-year historical average, the duration value of 20 weeks used by the Entergy is 29% higher than the average value of 15.5 weeks. This conservatism in the loss of work duration assumed by Entergy is judged to offset the regional lost income variation cited by ISR.

We also note that, while some of the impacted workers would be expected to lose their jobs due to the radiological impacts to their employment location, many of the impacted workers would be expected to retain their jobs and have their work shifted to a new location outside of the affected area. Many of these workers would be expected to be gainfully employed in the transition process associated with preparing a new facility and ramping up production. For many knowledge-based industries (*e.g.*, banking) prevalent in the New York City area, employee down-time may be limited due to the lack of specialized equipment that is required for work to recommence.

Based on the above considerations, we judge the POPCST value used in the IPEC SAMA analysis to be reasonable and appropriate for such an analysis.

6. <u>Other Sensitive Parameters</u>

Q158. Did ISR review any other MACCS2 input parameters relevant to Entergy's offsite economic cost calculation?

A158. (GAT, KRO) Yes. ISR evaluated the effect of the following additional sensitive parameters on the OECR: property depreciation rate (DPRATE), societal discount rate for property (DSRATE), and nonfarm wealth improvements fraction (FRNFIM). Lemay Test. at 61.

Q159. What did ISR conclude from its review of those inputs?

A159. (GAT, KRO) ISR determined that Entergy's alleged use of Sample Problem A values "sometimes led Entergy to overestimate the OECR and sometimes led Entergy to underestimate the OECR." Lemay Test. at 61. However, ISR noted that the overall effect of using "more appropriate values" for the remaining sensitive parameters "was negligible" on the final cost calculation. *Id.* at 61-62. This is reflected in that fact that ISR's proposed values for DPRATE, DSRATE, and FRNFIM (20%, 5-7%, and 90%, respectively) are identical or comparable to those used by Entergy (20%, 12%, and 80%, respectively). *See* ISR Report at 32 (Tbl. 13). Thus, ISR did not propose significantly different values for these three parameters.

VII. SUMMARY AND CONCLUSIONS

Q160. Please summarize your conclusions with respect to NYS's claims that Entergy has materially underestimated the total economic cost of a severe nuclear accident at IPEC, and that this alleged underestimation is primarily a result of: (1) Entergy's use of MACCS2 Sample Problem A input values for the CHRONC module and (2) Entergy's use of costs and times for decontamination that are unrealistic given current known decontamination data and the complexities of an urban to hyper-urban area such as that surrounding IPEC.

A160. (LAP, KRO, GAT) We conclude that NYS's claims lack both factual and technical merit. Although NYS presents a significant amount of technical data, the development and application of those data to the IPEC SAMA analysis is fraught with errors, as summarized below.

1. NYS fails to recognize that the SAMA analysis is intended to estimate average consequence results for the entire 50-mile radius region from the IPEC site (an area of approximately 7,854 miles), not just the comparatively small region of New York City, which comprises approximately 2% of the SAMA analysis region. NYS and its expert, Dr. Lemay,

attempt to scale up certain cost estimates related to the New York City portion without including commensurate scaling down of estimates for the 98% of the SAMA analysis region that is outside New York City. *See*, *e.g.*, A121, *supra*, related to ISR's use of the Luna Paper.

2. NYS and Dr. Lemay portray the IPEC MACCS2 analysis cost parameters as being arbitrarily based on the MACCS2 Sample Problem A distributed with the MACCS2 code. While the cost parameters used in the IPEC analysis are consistent with Sample Problem A, these parameter inputs were utilized based on their development and use for NUREG-1150 analyses conducted by the NRC and Sandia National Laboratories. These values have a long-established and appropriate technical basis (*see*, *e.g.*, A74-A78) and continue to be used today in state-of-the-art PRAs and SAMA analyses.

3. NYS and Dr. Lemay fail to demonstrate explicitly whether or how any of their suggested MACCS2 input data changes would impact the conclusions of the IPEC SAMA analysis by changing a non-cost-beneficial SAMA candidate to a cost-beneficial candidate. Despite their focus on activities associated with MACCS2 calculations, NYS and its expert fail to address any corresponding impacts on the population dose results calculated by MACCS2 and employed in the SAMA analysis. Relative to decontamination activities as modeled by MACCS2, population dose results tend to move in the opposite direction of economic impact results, such that an increase in MACCS2 cost impact results is often accompanied by a decrease in population dose results (see A83). Both the population doses and economic costs estimated by MACCS are factored into the determination of which SAMA candidates are potentially cost-beneficial.

4. NYS and Dr. Lemay rely heavily on data contained in the Sandia *Site Restoration Report (SRR)* to develop alternative decontamination cost estimates but fail to properly or accurately account for the following attributes of that study:

a. The SRR serves to develop cost estimates for remediation of a *plutonium dispersal event.* The focus on plutonium in the SRR significantly increases the SRR estimated remediation costs in terms of its assumption that any area requiring a DRF greater than 10 would require complete demolition (see A89-A90). This runs counter to the experience of remediation for Chernobyl, where DRFs of up to 15 were obtained without resorting to complete demolition (see A92).

b. The SRR focused on relatively small areas for remediation and did not fully investigate attributes that would be pursued for a significantly larger cleanup effort, such as segregating non-radiological waste from radiological waste, employing waste volume reduction techniques, and minimizing the costs for associated with on-site disposal (see A134-A135).

c. The SRR cost estimates developed and used by Dr. Lemay for his non-farm decontamination cost estimates (for MACCS2 variable CDNFRM) include cost categories addressed by other variables in MACCS2 (see A121).

5. NYS and Dr. Lemay rely on data contained in a brief technical paper by Luna to scale up projected decontamination costs associated with postulated decontamination for New York City. NYS and Dr. Lemay, however, fail to apply their methodology consistently and scale *down* the decontamination costs associated with the remaining 98% of the SAMA analysis area. Additionally, the Luna Paper remediation cost estimates are based on the SRR and therefore contain all of the shortcomings (when applied to the IPEC SAMA analysis) summarized above.

6. NYS and Dr. Lemay rely on data contained in a brief technical paper by Reichmuth and brief references to other studies by Reichmuth to provide another estimate for decontamination costs but fail to properly or accurately account for the following attributes:

a. The application by Reichmuth for radiological cleanup of a radiological dispersion device in NYC is based on costs associated with the September 11, 2001 attacks on the World Trade Center, *an attack that did not involve any radiological material*. The details of how Reichmuth estimated "preliminary" costs for a radiological dispersal event (with essentially no physical damage) from the attacks on the World Trade Center are not presented in the Reichmuth paper for critical review (see A136).

b. The graphical presentation of cost estimates for a modeled cesium-137 attack on Vancouver contains costs that are outside the scope of the MACCS2 variable for decontamination cost (CDNFRM). Dr. Lemay applied the full costs while it appears only 15% is applicable (and the basis for this portion is not presented for critical review) (see A137).

c. The Reichmuth studies appear to use the same cost model as the SRR and therefore contain all of the shortcomings (when applied to the IPEC SAMA analysis) summarized above.

7. NYS and Dr. Lemay rely on data contained in the CONDO software tool for estimating decontamination costs in the United Kingdom but fail to properly or accurately account for the following attributes:

a. Assigned decontamination techniques with overall decontamination levels are grouped as "light decontamination" and "heavy decontamination" categories. However, they are chosen without articulating a technical basis and seem to span overlapping ranges of decontamination effectiveness. One technique, in particular, appears in both light and heavy categories of decontamination effectiveness, which suggests that the two schemes of techniques are ill-defined (see A143).

b. Although the CONDO dataset contains cost estimating data for 61 decontamination techniques, Dr. Lemay relied upon only seven techniques and the resulting Lemay decontamination cost estimates are driven by "vacuuming, cleaning and washing" of interior surfaces. No justification is presented for why vacuuming of interior surfaces should dominate the cost estimates (see A144).

c. The CONDO datasets present data for three different population category ranges (*i.e.*, rural, semi-urban, and urban). Dr. Lemay invents a fourth population category (*i.e.*, hyper-urban) and for some cost estimates disregards the CONDO cost category definitions and applies a higher cost category than is applicable based on the population density in the IPEC SAMA analysis region. The required population densities to meet the CONDO criteria are not met in most of the SAMA analysis region for this case, and thus this particular sensitivity analysis is invalid. No justification is presented for this misapplication of CONDO methodology (see A145).

8. NYS and Dr. Lemay rely on data contained in a report produced by Denmark's Risø National Laboratory to develop an additional estimate of decontamination costs. The development of these cost estimates, however, are not justified and presented in sufficient detail to allow an

adequate evaluation (See A143). While a spectrum of decontamination effectiveness levels is documented in the Risø report, ISR infers that the report only supports “light decontamination” work. Also, labor cost information is not contained in the Risø report, and it is unclear from the limited information presented in the ISR Report what labor cost data were included by Dr. Lemay in his assessment.

9. NYS and its expert Dr. Lemay propose a wide range of decontamination costs based on their application of different data sources. Subject to the comments above regarding the erroneous application of these data sources, the development of such widely differing values demonstrates the importance of MACCS2 analysts using parameter values that have been well vetted by the PRA community, the national laboratories, and the NRC. The MACCS2 values used by Entergy for the IPEC SAMA analysis, based on NUREG-1150, are such values.

10. Dr. Lemay proposes that the decontamination time modeled in MACCS2 variable TIMDEC does not reflect actual decontamination experiences and Dr. Lemay proposes values that are so long they are far outside the accepted input range of the MACCS2 code. Dr. Lemay fails to correctly characterize the TIMDEC parameter, and specifically fails to recognize that:

a. The TIMDEC values used by IPEC in their MACCS2 SAMA analysis are based on precedent and have a long, established history of use being developed by Sandia National Laboratories under the sponsorship of the NRC (See A105-A106).

b. TIMDEC sets the minimum time that individuals are relocated and a long TIMDEC value can defeat MACCS2 internal decontamination optimization scheme regarding resettlement of temporarily relocated persons (see A26, A102, & A103).

c. TIMDEC is not intended to represent the time until the cessation of all decontamination activities. Continued decontamination activities following population resettlement as modeled by TIMDEC is not incongruous (see A102-A103).

d. TIMDEC is an "average" decontamination time with some activities expected to be completed prior to this time and some completed subsequent to this time (see A105).

11. NYS and Dr. Lemay propose that the per capita cost of long term relocation (MACCS2 variable POPCST) should be higher and based on the current term for unemployment benefits. We disagree and conclude that the long term historical unemployment duration is a better benchmark. Using this benchmark the IPEC value of POPCST is judged conservative and reasonable for use for the SAMA analysis.

12. Computer code use for PRA applications as well as those supporting NEPA applications relies on consistency and quality assurance standards in the development, maintenance and use of software. Altering the MACCS2 source code to accept user-preferred, out-of-range input values, and then running the modified code without seeking *independent* verification of proper code functionality, is not the norm. Indeed, it is ill advised, as such a practice potentially violates the MACCS2 user's agreement and runs counter to configuration control and software quality assurance principles followed by all of the nuclear industry. Yet this was done to achieve ISR's results, which alone should render them as invalid bases for challenging Entergy's results.

13. In summary, based on our review of the IPEC SAMA analysis, we conclude that:

- Entergy's inputs and assumptions relating to decontamination costs are both reasonable and appropriate for a SAMA analysis and comply with NEPA and related NRC requirements.

- The effective use of the 95th percentile core damage frequency (CDF) results for determining cost-beneficial SAMAs conservatively incorporates a factor of 2.1 and a factor of 1.4 for IP2 and IP3, respectively. *See* A62 & n.3. This conservatism provides margins for other potential uncertainties associated with the overall SAMA analyses for IP2 and IP3.

- Entergy followed the guidance in the NRC-endorsed industry guidance document NEI 05-01 Rev. A to perform its SAMA analyses for IP2 and IP3, and appropriately used MACCS2, the only NRC-recognized computer code available in the U.S. that is capable of meeting all of the offsite consequence requirements of a SAMA analysis, including calculating population dose and economic cost consequences.

Q161. Does this conclude your testimony?

A161. (LAP, KRO, GAT) Yes.

Q162. In accordance with 28 U.S.C. § 1746, do you state under penalty of perjury that the foregoing testimony is true and correct?

A162. (LAP, KRO, GAT) Yes.

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